Curtis Creek Watershed Diagnostic Study

NEWTON AND JASPER COUNTIES, INDIANA

April 11, 2003

Prepared for:

Newton County Soil and Water Conservation District
213 E. North Street
Morocco, Indiana 47963

Prepared by:

JFNew

c/o Sara Peel, Project Manager
708 Roosevelt Road
Walkerton, Indiana 46574
574-586-3400

CURTIS CREEK WATERSHED DIAGNOSTIC STUDY
EXECUTIVE SUMMARY

The Curtis Creek Diagnostic Study is a comprehensive examination of Curtis Creek and its surrounding watershed. In 2002, with funding from the Indiana Department of Natural Resources Lake and River Enhancement (LARE) Program, the Newton County Soil and Water Conservation District hired the team of Indiana University and JFNew to conduct the study. The purpose of the study was to describe the historical and existing condition of the watershed, identify potential problems, and make prioritized recommendations addressing these issues. It included a review of historical studies, several mapping exercises, an aerial and windshield tour of the watershed, an assessment of chemical, biological, and physical stream health, and interviews with watershed residents and representatives from local and state agencies.

The Curtis Creek Watershed encompasses 26,572 acres of Newton and Jasper Counties from Fair Oaks, Indiana south to Curtis Creek's confluence with the Iroquois River. Historically, much of the watershed was tall grass prairie; less than 2% of natural tall grass habitat exists within the watershed today. The watershed is 73% row crop agriculture. Conservation tillage is utilized on 52% of soybean fields and 18% of corn fields. All tributary streams sampled are considered modified warmwater habitat due to their primary use as drainage ditches. The soils in the northern portion of the watershed, the area north of State Road 14, are predominantly blow sand, while soils in the southern portion of the watershed consist mostly of silty clay loams of low erosion potential. Three facilities with permitted point source discharges operate in the watershed. The watershed also houses three confined feeding operations containing a total of approximately 12,000 head of dairy cattle and 6,050 head of hogs.

The study documented high levels of ammonia-nitrogen, nitrate-nitrogen, phosphorus, and *E. coli* in the watershed streams. The macroinvertebrate Index of Biotic Integrity (mIBI), an index which utilizes invertebrate community structure to measure water quality, documented a range of moderately impacted (2.25) to slightly impaired (5.25) macroinvertebrate communities. Habitat as assessed using the Qualitative Habitat Evaluation Index (QHEI) was also less than optimal for aquatic life uses at most sites. Water quality samples taken during storm events exceeded state standards for some chemical parameters and for *E. coli* at many sample sites.

Approximately 100 land treatment or restoration projects are recommended to reduce soil erosion and improve the biological, chemical, and physical condition of streams throughout the study area. Priority subwatersheds identified include the State Road 114 Subwatershed followed by the Yeoman Ditch and Long Ditch Subwatersheds. Recommended land management treatments in the watershed include: wetland restoration, filter strip installation, buffer zone establishment, bank stabilization, livestock fencing, revegetation of exposed areas, and grassed waterway construction. Coordination with the permitted dischargers and the County Drainage Board, along with management at the watershed-level and public education and outreach, are also recommended.

ACKNOWLEDGEMENTS

This Watershed Study was performed with funding from the Indiana Department of Natural Resources Division of Soil Conservation and the Newton County Soil and Water Conservation District. JFNew and Indiana University School of Public and Environmental Affairs documented the historical information available, completed tributary stream sampling for nutrient and sediment loading, and modeled nutrient and sediment loading to major rivers. Carla Orlandi of the Newton County SWCD provided initiative and assistance in getting this study started and completed. Contributors to this study included: Todd Davis, Stacey Sobat, and Chuck Bell with the Indiana Department of Environmental Management (IDEM); Mark Evans with the Purdue Cooperative Extension Agency; Jill Hoffmann, Jennifer Bratthauer, Ron Hellmich, Nathan Brindza, and Bob Robertson with the Indiana Department of Natural Resources (IDNR); Larry Strole and Hank Coussens, Newton County SWCD board supervisors; Dan Ritter of the Newton County Purdue Cooperative Extension Agency; Mike Manning of the Jasper County Purdue Cooperative Extension Agency; Ruth Ellen Haywood of the Newton County Health Department; Sandra Parks of the Jasper County Health Department; Jeff LaCosse of the Newton County Surveyors Office, Carl Ramsey of the Fair Oaks Dairy Farm, Mike Zickmund, a local landowner, and Lyn Hartman of Hoosier Riverwatch. Authors of this report included William Jones, Melissa Clark, Sean Graham, Becca Barnes, Wendy Drake, and Sarah Panter at Indiana University and Sara Peel, Marianne Giolitto, and Cornelia Sawatzky at JFNew. Brian Majka of JFNew provided GIS maps.

TABLE OF CONTENTS

Page

TABLE OF FIGURES

Page

Page

Page

TABLE OF TABLES

Page

Page

Page

TABLE OF APPENDICES

INTRODUCTION

The Curtis Creek Watershed is located northwest of Rensselaer and southwest or Fair Oaks in Jasper and Newton Counties, Indiana (Figure 1). The watershed drains approximately 26,572 acres (10,753 ha). The Curtis Creek Watershed encompasses most of three 14-digit watersheds: the Curtis Creek Headwaters Watershed (HUC 07120002040010), the Curtis Creek-Long Ditch (Mount Ayr) Watershed (HUC 07120002040020), and the Iroquois River-Curtis Creek-Yeoman Ditch Watershed (HUC 0712002040030; Figure 2). The study area lies within Newton and Union Townships in Jasper County and Colfax, Jackson, and Lincoln Townships in Newton County. For the purpose of this study, the watershed was further divided into ten smaller subwatersheds (Figure 3).

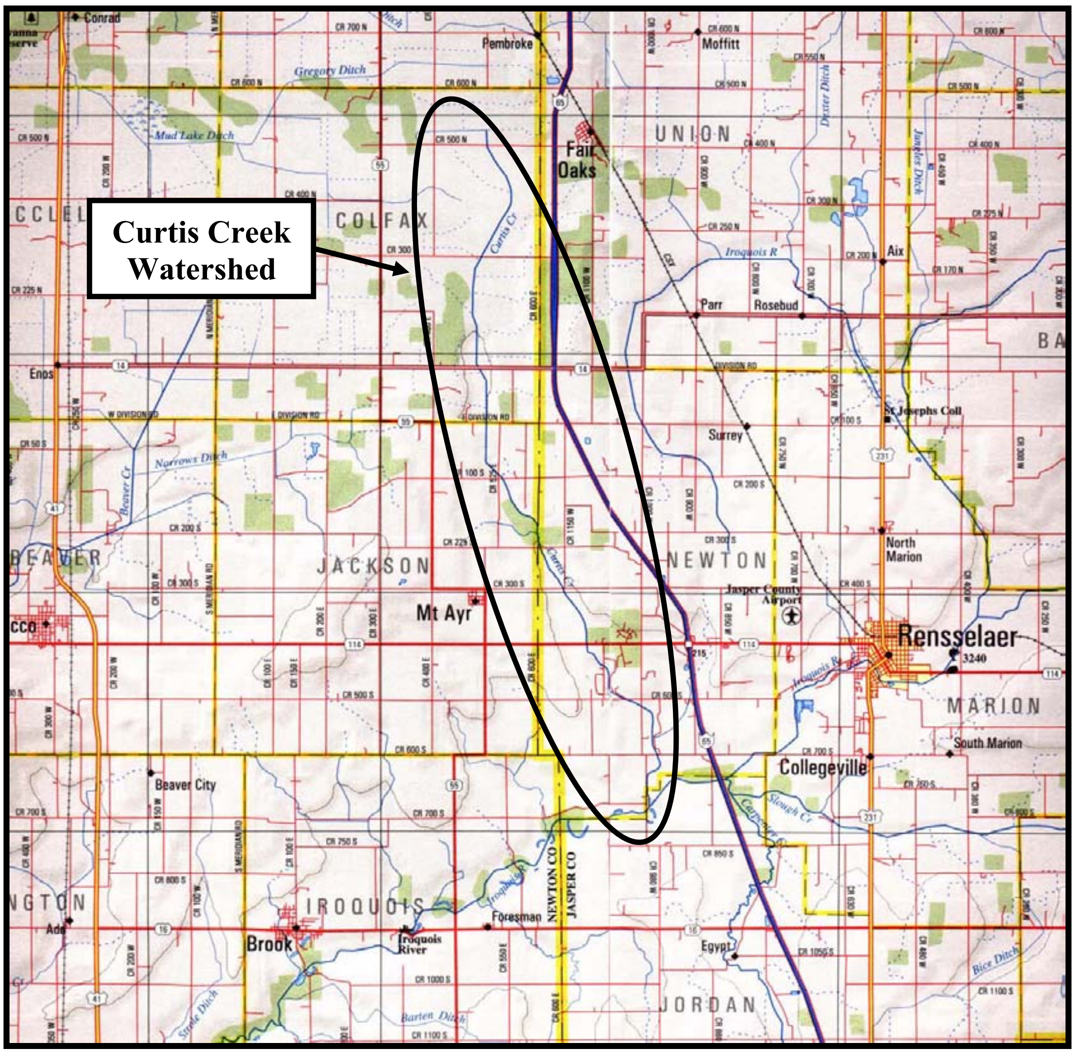


FIGURE 1. Study location map.

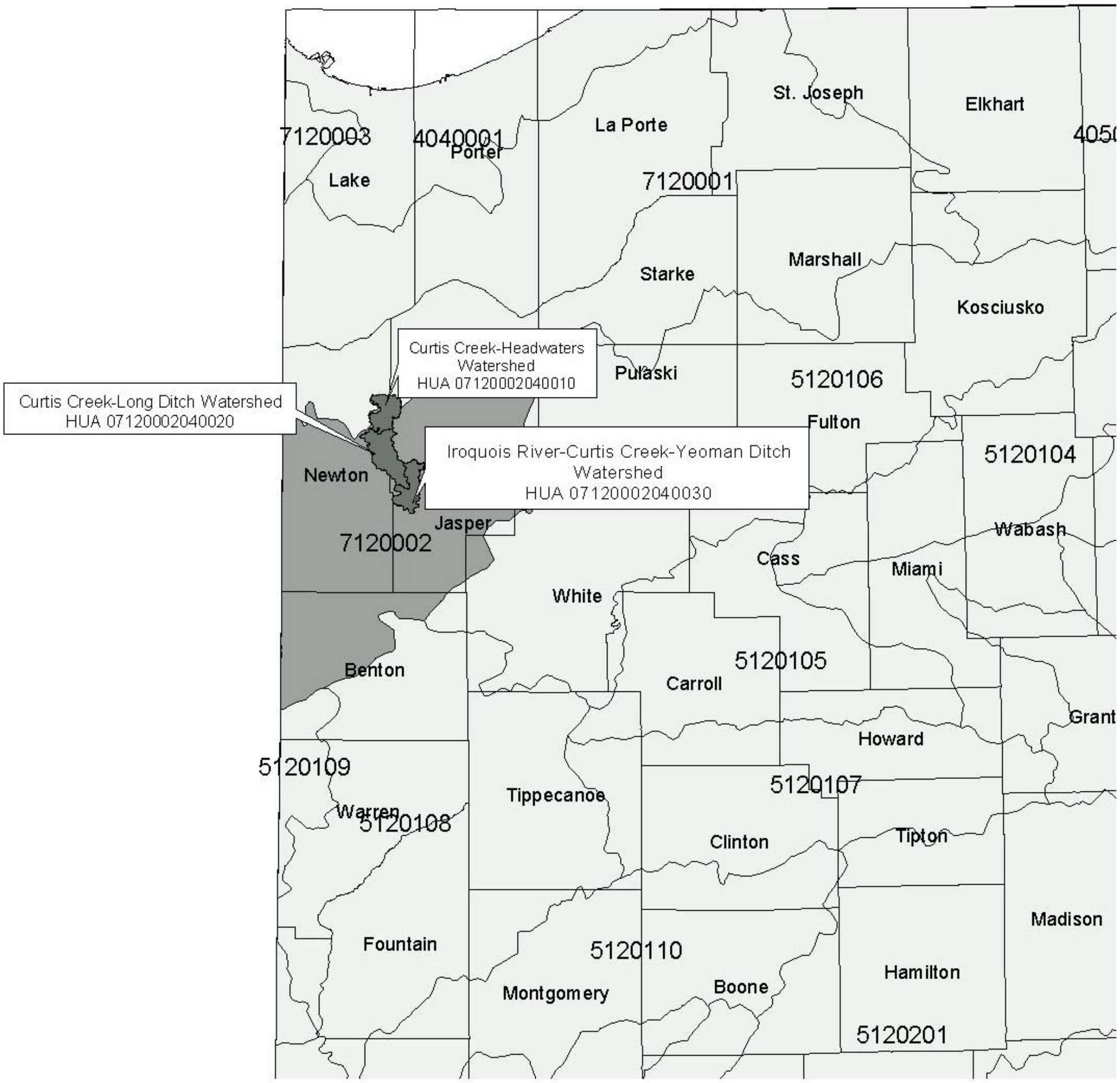


FIGURE 2. The three 14-digit watersheds that comprise the Curtis Creek Watershed within the Iroquois River Basin.

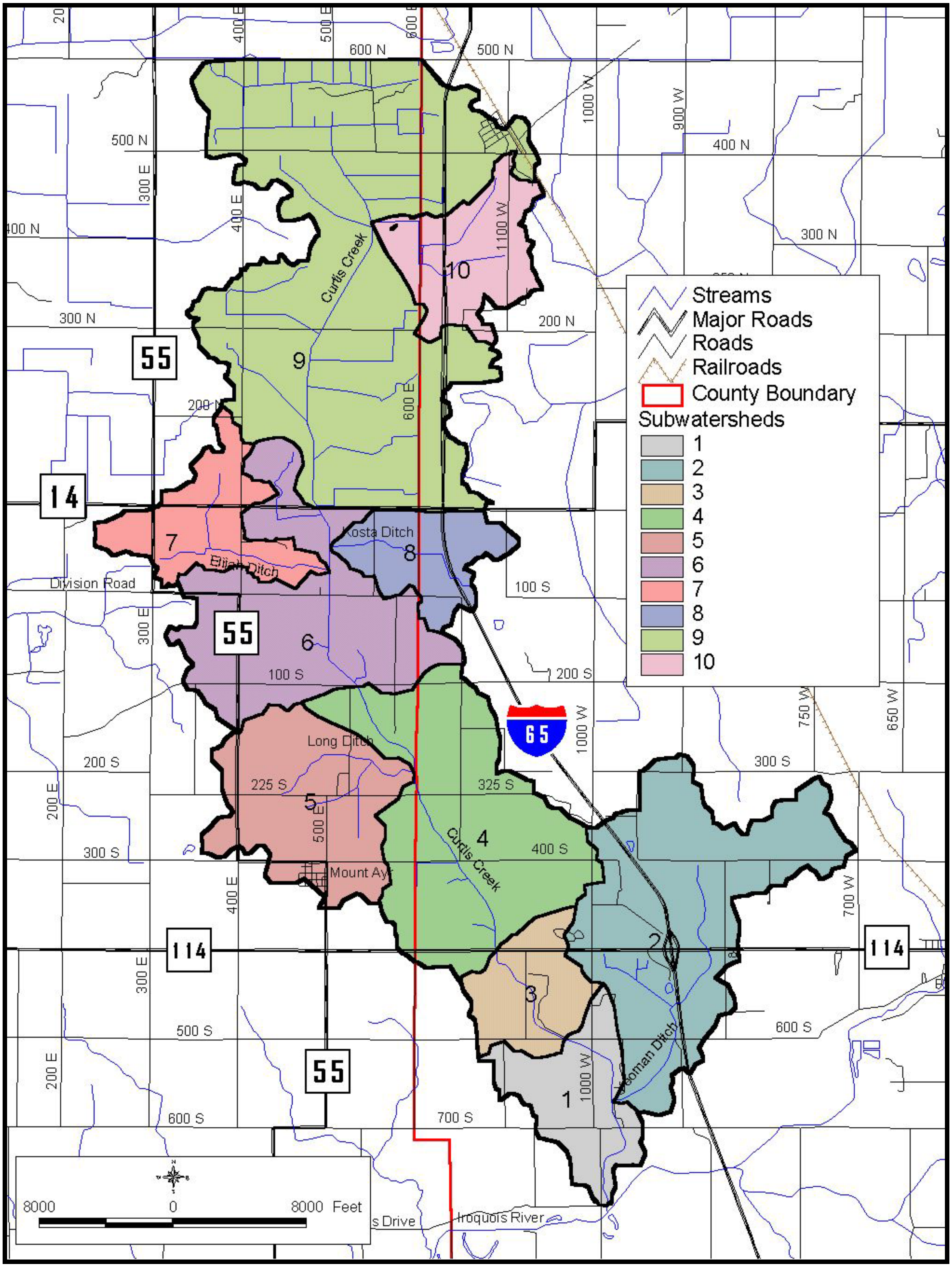


FIGURE 3. Study subwatersheds.

The watershed is part of the 8-digit Iroquois River Watershed HUC 07120002 (Figure 2). Water from Curtis Creek discharges into the Iroquois River just southwest of Rensselaer, Indiana. The Iroquois River flows west where it joins the Kankakee River south of Kankakee, Illinois. The Kankakee River is a tributary of the Illinois River which converges with the Mississippi River in southwestern Illinois.

It is important to note that all the study streams except private lateral ditches north of State Road 14 are legal drains. Legal drains are necessary for water conveyance to sustain a variety of land uses, including agriculture. Disturbance to the legal drain system is inevitable due to periodic drainage improvement projects. Projects constructed within the drainage easement require County Drainage Board permission. Some projects may not be permitted if they impede drainage. Other permits from the U.S. Army Corps of Engineers (ACOE), the Indiana Department of Environmental Management (IDEM), and the Indiana Department of Natural Resources (IDNR) may also be required depending on the type of project.

The drainage basin of Curtis Creek was formed during the most recent retreat of the Pleistocene or Quaternary Era. The advance and retreat of the Wisconsinian glaciers and the deposits left by the glacial lobes shaped much of the landscape found in the northern two-thirds of Indiana (Wayne, 1966). The soils in the northern portion of the watershed formed in low relief sands and gravels of the Kankakee Outwash and Lacustrine Plain (Ulrich, 1966). The sandy soils tend to be loose and susceptible to drought. Nearer the confluence with the Iroquois River, Curtis Creek Watershed soils developed in the Prairie Till Plain (Ulrich, 1966). These soils are darker in color, higher in organic matter, and "formed in moderately heavy limy glacial till deposits" (Ulrich, 1966).

The study watershed is located in the Grand Prairie Natural Region (Homoya et al., 1985). The Grand Prairie Natural Region occupies most of the northwest area of the state and is bordered by the Valparaiso Moraine in the north, the Wabash River Valley in the south, and the Maxinkuckee Moraine in the east. Prior to European settlement, expanses of tall grass prairie and savanna covered the region, and many of the species characteristic of eastern deciduous forests are not found in the area (Homoya et al., 1985). As only remnants of the Grand Prairie are known to exist, this region is considered the most altered of all natural regions in the state. Little is known about the prairie plant community composition; however, small remnants of upland prairie in railroad right-of-ways and in old cemeteries contain little and big bluestem, Indian grass, switchgrass, side-oats grama, compass plant, and many other species. Sand dwelling species, like porcupine grass, prairie dropseed, longleaf reedgrass, prairie talinum, puccoon, primrose violet, and the dwarf dandelion, were associated with deposits of dune sand (Homoya et al. 1985). Forests such as small oak groves were primarily associated with riparian corridors. The first plat of Indiana, *circa* 1816, documented tall grass prairie as comprising about 17% of the original vegetation of the state (Petty and Jackson, 1966). Homoya et al. (1985) described streams of the Grand Prairie Natural Region as being silty and of low gradient. Extensive channelization of stream in the area has resulted in severe alterations to stream communities (Homoya et al., 1985).

Changes in land use have altered the watershed's natural landscape. Settlers to the region drained wet areas and cleared forests in order to farm soils rich in both nutrients and humic material (decaying organic matter). However, this layer of rich soil was thin in many places and years of crop removal and erosion depleted nutrient supplies. Around 1850, fertilization with potassium and phosphorus began. Fertilization had no effect on crop yield until 1940 when Dr. George Scarseth discovered that massive doses of nitrogen could significantly increase productivity. Technology and industry have increased and continue to increase farm production. Today, approximately 85% of the watershed is utilized for agricultural purposes.

Installation of subsurface tile drain networks, excavation of drainage channels, and straightening of streams has allowed for the conversion of prairies and wetlands to agricultural land use. The effect of these drainage activities on water quality has been negative, resulting in off-site, downstream water flow and quality concerns. In a review of agricultural practices and their impacts on the natural structure and function of aquatic systems, Osmond and Gale (1995) concluded that effects other than water quality problems have emerged. These include alterations in water quantity, habitat structure, and energy transfer within streams.

Few studies have been conducted to document water quality and health within the Curtis Creek Watershed. However, the 2002 Indiana Department of Environmental Management 303(d) list prepared for the U.S. Environmental Protection Agency indicates non-support of biotic community beneficial uses due to low dissolved oxygen levels and high levels of nutrients, total dissolved solids, and chlorides for the Yeoman Ditch. Evidently, human impacts within this area of the Curtis Creek Watershed are having an adverse effect on water quality and beneficial uses.

Because there is little information about this watershed and in order to gain a better understanding of it, the Newton County Soil and Water Conservation District (SWCD) applied for and received funding through the Indiana Department of Natural Resources (IDNR) Lake and River Enhancement (LARE) Program to complete a watershed diagnostic study. The purpose of this study was to describe the conditions in the watershed, identify potential problems, and make prioritized recommendations addressing these problems. This study included a review of historical data and information; correspondence with landowners, business owners, and state and local regulatory agencies; collection of stream water quality samples and benthic macroinvertebrates; stream habitat quality evaluation; and field investigations identifying land use patterns and locations for best management practice (BMP) installation. This report documents the results of the study.

REVIEW OF EXISTING INFORMATION

Population and Demographics

Population sizes have dramatically increased in Jasper and Noble Counties since 1990 (STATS Indiana, 2002). The 2000 census recorded 20% more people living in Jasper County and 7% more people living in Newton County than compared to 10 years ago. On average, about 39 people per square mile live in the five townships encompassed by the study watersheds (Table 1).

TABLE 1. Population structure of the five townships that are fully or partially encompassed by the Curtis Creek Watershed.

County	Township	Township Population	People/Square Mile
Jasper	Union	1,382	38
Jasper	Newton	733	20
Newton	Colfax	176	5
Newton	Jackson	439	12
Newton	Lincoln	4,268	119

Source: STATS Indiana, 2002.

Physiography and Geology

The surficial physiography and geology of the Curtis Creek Watershed is the result of the most recent glacial period known as the Wisconsinian Age that began about 70,000 years ago. Prior to the Wisconsinian Age, Indiana had been glaciated twice, though the Wisconsin glacier can be credited with building the topography in northwestern Indiana. During the main advance about 21,000 years ago, the Wisconsinian glacier covered two-thirds of the state. Numerous glacial advances and retreats resulted in ground and end moraine deposition and the formation of Indiana topography as it is known today.

The first two retreats of the Lake Michigan and Lake Erie Lobes of the Wisconsinian Age glaciers that came from the north and northeast deposited the Iroquois, Shelbyville and Crawfordsville/Chatsworth Moraines (Figure 4) and established the current topography of the Curtis Creek Watershed about 20,000 years ago. Consequently, these retreats created a "glaciated plain where a variety of unconsolidated deposits of Wisconsinian Age are present including dune sand, lacustrine sediments, outwash plain sediments (sand and gravel), and till" (end and ground moraines) (Homoya et al., 1985). These deposits are collectively called the Trafalgar Formation. These Trafalgar tills are mostly composed of bedrock from Canada where the glaciers originated.

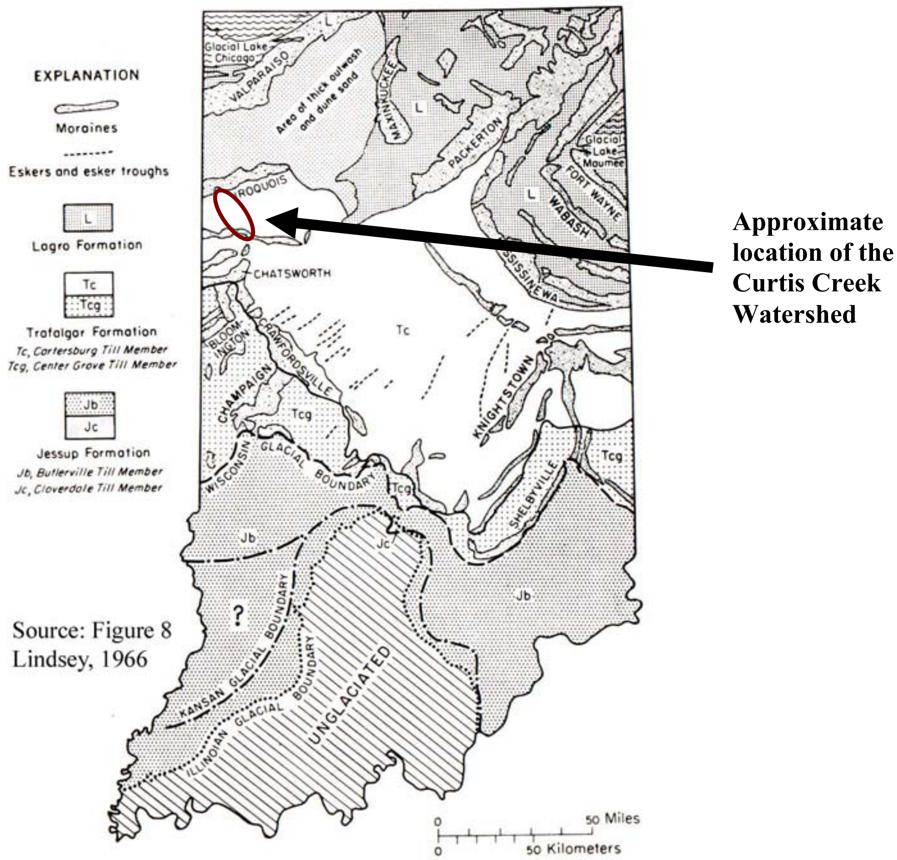


FIGURE 4. Moraine deposits in northern Indiana from the Wisconsin Glacial Period. Tc indicates areas of the Trafalgar formation, while L is the Lagro formation.
Source: Figure 8 from Lindsey, 1966.

In physiographic terms, the Curtis Creek Watershed is part of the Northern Moraine and Lakes Region, specifically the Kankakee Outwash and Lacustrine Plain (Schneider, 1966). The Kankakee Outwash and Lacustrine Plains are characterized by low, poorly drained areas underlain mostly by sand. Wisconsinian glaciers deposited a majority of the sand via outwash and meltwater. Prevailing westerly winds modified the topography of the plain through sand redistribution over the past 20,000 years.

The glacial topography of the area is underlain by dolomite/siltstone/shale bedrock formed during the Silurian Age about 40 million years ago (Gutschick, 1966). Before glaciers deposited drift over the area, the landscape consisted of dolomite, limestone, chert, siltstone, and shale bedrock. This bedrock is now covered by a sand cap which varies in thickness from a few inches to 3-4 feet (Barnes and Osterholz, 1998).

Watershed Physical Characteristics

The Curtis Creek Watershed totals approximately 26,572 acres (10,753 ha or 41.5 square miles) and is part of the Iroquois River Basin. Water from Curtis Creek discharges into the Iroquois River southwest of Rensselaer in Jasper County. The Iroquois River joins the Kankakee River in Kankakee, Illinois. Eventually the Kankakee River converges with the Illinois River south of Chicago, Illinois. The Illinois River, in turn, is part of the larger Mississippi River system.

Tables 2 and 3 contain overview data for the watershed including subwatershed area and stream lengths for all named streams. Subwatershed boundaries were defined based on topography and the location of chemical, physical, and biological sampling sites for this study. It is often desirable to consider subwatersheds or subdrainages because: 1) human communities are organized within small areas (e.g. the hotels and restaurants located near the intersection of State Road 114 and Interstate 65 in the Yeoman Ditch Subwatershed); 2) the subdrainage scale allows for the identification of areas where specific management practices can be recommended and instituted; 3) large watershed units may be too expensive to restore, while treatment of small areas may provide measurable water quality improvement (O'Leary et al., 2001). Additionally, watershed division allows for prioritization of resources to land areas of greatest concern and where conservation practices may have the greatest benefit. It is important to note that since the headwaters area of the watershed possesses little relief (there is 5 feet of fall between the top of the watershed and State Road 14), human activities can easily alter subwatershed configurations and areas. In other words, subwatersheds may not follow topographical relief patterns in heavily tiled areas. Subwatersheds shown in Figure 3 are based on drainage route information available when water sampling was conducted in 2002. Excavation of new ditches and filling of old ditches since summer of 2002 may have altered watershed hydrology as presented in this report.

TABLE 2. Watershed area for the ten study subwatersheds.

Subwatershed	Subwatershed Number	Watershed Area
Mouth Subwatershed	1	1,273 acres (515 ha)
Yeoman Ditch Subwatershed	2	3,816 acres (1,544 ha)
Golf Course Subwatershed	3	1,037 acres (1,486 ha)
State Road 114 Subwatershed	4	3,672 acres (1,486 ha)
Long Ditch Subwatershed	5	2,216 acres (897 ha)
County Road 100 South Subwatershed	6	3,061 acres (1,239 ha)
Elijah Ditch Subwatershed	7	1,296 acres (524 ha)
Kosta Ditch Subwatershed	8	1,030 acres (417 ha)
Headwaters Subwatershed	9	7,929 acres (3,209 ha)
Fair Oaks Subwatershed	10	1,241 acres (502 ha)
Total		**26,573 acres (10,754 ha)**

TABLE 3. Stream length of all named streams in the Curtis Creek Watershed.

Creek/Ditch	Stream Length (miles)	Stream Length (km)
Curtis Creek	14.24	22.93
Yeoman Ditch	4.82	7.75
Long Ditch	3.34	5.38
Elijah Ditch	2.96	4.77
Kosta Ditch	1.90	3.05
Unnamed Tributaries	30.11	48.47
Total	**57.37**	**92.36**

Climate

Indiana Climate

Indiana's climate can be described as temperate with cold winters and warm summers. "Imposed on the well known daily and seasonal temperature fluctuations are changes occurring every few days as surges of polar air move southward or tropical air moves northward. These changes are more frequent and pronounced in the winter than in the summer. A winter may be unusually cold or a summer cool if the influence of polar air is persistent. Similarly, a summer may be unusually warm or a winter mild if air of tropical origin predominates. The action between these two air masses of contrasting temperature, humidity, and density fosters the development of low-pressure centers that move generally eastward and frequently pass over or close to the state, resulting in abundant rainfall. These systems are least active in midsummer and during this season frequently pass north of Indiana" (National Climatic Data Center, 1976). Prevailing winds in Indiana are generally from the southwest but are more persistent and blow from a northerly direction during the winter months.

Flooding is common in Indiana and occurs in some part of the state almost every year. The months of greatest flooding frequency are December through April. Causes of flooding vary from prolonged periods of heavy rain to precipitation falling on snow and frozen ground. The Curtis Creek Watershed experienced a prolonged period of flooding in May 2002. Storm flow sampling occurred on May 14, 2002. In the 2-3 days prior to sampling local rain gauges recorded 2.7 inches of rainfall; 3.97 inches of rain fell in the two weeks prior to sampling. Due to extreme volumes of rainfall throughout the Midwest, all major rivers including the Mississippi, the Illinois, and the Iroquois reached or exceeded flood stage.

Curtis Creek Watershed Climate

The climate of the Curtis Creek watershed is characterized as having four well-defined seasons of the year. Winters temperatures average 25ºF (-3.8ºC), while summers are warm, with temperatures averaging 72ºF (22.2ºC). The growing season typically begins in late April and ends in early September. Yearly annual rainfall averages 37.32 inches (94.8 cm). Winter snowfall averages of about 28.3 inches (71.9 cm). During summers, relative humidity varies from about 62 percent in mid-afternoon to near 82 percent at dawn. Prevailing winds typically blow from the southwest.

In 2001, over 39 inches (99 cm) of precipitation (Table 4) was recorded at Rensselaer in Jasper County (Purdue Applied Meteorology Group, 2002). When compared to the 30-year average rainfall for the area, 2001 exceeded the average by almost three inches. Year 2001 was characterized by significant wetter-than-normal and drier-than-normal periods. January and March were uncharacteristically dry. Conversely, in October of 2001 Jasper County received 6.5 inches more rain than would have been received by a normal October of 2001. The Curtis Creek Watershed received more rainfall than normal during 2002; a total of nearly 40.5 inches (102.8 cm) of precipitation fell in 2002. This is mainly due receiving double the normal volume of rainfall during May; higher than average rainfall occurred during July and August as well.

TABLE 4. Monthly rainfall data (in inches) for year 2001 and 2002 as compared to average monthly rainfall. All data was recorded at the Rensselaer gage station in Jasper County. Averages are 30-year normals based on available weather observations taken during the years of 1961-1990 (Purdue Applied Meteorology Group, 2002).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
2001	0.97	2.14	0.66	3.59	2.63	4.48	5.50	3.43	3.12	9.10	2.07	1.59	39.28
2002	2.76	2.60	3.44	3.87	6.05	2.65	5.84	5.49	2.59	1.68	1.52	1.28	40.49
Average	1.78	1.36	2.77	3.78	3.46	4.07	3.92	3.62	3.67	2.51	2.71	2.83	36.20

Soils

Introduction

The soil types found in the Curtis Creek Watershed within Jasper and Newton Counties are a product of the original material deposited by the glaciers that covered the areas 12,000 t0 15,000 years ago. The main parent material found in the counties is glacial outwash and till, ice-contact sand and gravel deposits, alluvium, and organic materials that were left as the glaciers receded. The interaction of these parent materials with the physical, chemical and biological variables found in the area (climate, plant and animal life), time, and the physical and mineralogical composition of the parent material formed the soils located in the two counties today.

Due to the variable and unconsolidated nature of the Wisconsinian Age glacial deposits, seven different soil associations cover the study area. Table 5 contains information on these general soil associations and where they may be found within the general topography of the watershed.

TABLE 5. Characteristics of general soil associations found within the study watershed.

County	Association	Description	Sand Texture	Formation Process	Location
Newton	Granby-Maumee-Zadog	loamy sands; sand; sandy clay loam	coarse	in outwash deposits	outwash plains; lake plains; depressional areas
Newton	Barry-Sumava-Octagon	loam; sandy loam	moderately coarse	in glacial till or outwash deposits	nearly level moraines; swale-swell topography
Newton/Jasper	Oakville-Morocco-Brems	sand; loamy sand	coarse	in outwash deposits	knolls; outwash plain ridges
Jasper	Rensselaer-Darroch-Nesius	loam; silt loam; fine sand	moderately coarse to coarse	in loamy and sandy outwash; sandy eolian deposits	depressional areas; outwash and lake plains; swale-swell topography
Jasper	Rensselaer, till substratum-Markton-Aubbeenaubbee	sand; loam; sandy loam; sandy clay loam	moderately coarse to coarse	in loamy and sandy outwash over loamy till	Slight depressional areas; uplands; swale-swell topography
Jasper	Parr-Ayr-Wawasee	loamy sand; sand; loam	moderately coarse to coarse	in loamy or sandy outwash over till	recessional moraines; ridges
Jasper	Suman-Craigmile-Prochaska	clay loam; sandy loam; loamy sand	moderately fine to moderately coarse	in silty and loamy alluvium over sandy deposits; in sandy alluvium	depressional areas; flood plains

Source: Smallwood and Osterholz, 1990; and Barnes and Osterholz, 1998

As the landscape encompassing the Curtis Creek Watershed transitions from the morainal formation of the Valparaiso Moraine to the outwash plain of the Iroquois River valley, the landscape's major soil associations transition from soil units consisting of fine sand and sandy loam materials to soil units consisting of more clay and silt materials. Consistent with this geologic shift, the soil associations covering the Curtis Creek Watershed shift from blow-sand dominated associations, such as Oakville-Morocco-Brems and Granby-Maumee-Zadog, to soils containing more silt and clay (Barry-Sumava-Octagon, Parr-Ayr-Wawasee, and Rensselaer, till substratum-Markton-Aubbeenaubbee) near the Newton County-Jasper County line. The Rensselaer-Darroch-Nesius and Suman-Craigmile-Prochaska soil associations cover the lower portion of the Curtis Creek Watershed.

Highly Erodible Soils

Soils in the watershed and their ability to erode or sustain certain land use practices, can impact the water quality of the river systems in the watershed. For example, highly erodible soils are, as their name implies, easily erodible. Soils that erode from the landscape are transported to waterways where they degrade water quality, interfere with recreational uses, and impair aquatic habitat and health. In addition, such soils carry attached nutrients, which further impair water quality by increasing production of plant and algae growth. Soil-associated chemicals like some herbicides and pesticides can kill aquatic life and damage water quality.

Table 6 lists the soil units considered highly erodible by the Natural Resources Conservation Service (NRCS). It is important to note that highly erodible soil designations are based on county-wide soil surveys, and the soils at various locations have not necessarily been field-checked. Jasper County lists two highly erodible soil types, while Newton County lists five highly erodible soil types. Of the seven highly erodible soil types present in Jasper and Newton Counties, Oakville fine sand (OaC) is the only highly erodible soil mapped in the Curtis Creek Watershed. The headwaters (north of State Road 14) of Curtis Creek, which lie within blow-sand, outwash deposits, are the only areas in the watershed which contain highly erodible soils. Downstream portions of the watershed, from State Road 14 south to the Iroquois River, do not contain any highly erodible soils.

TABLE 6. Soil units within the counties considered highly erodible by the NRCS offices of Jasper and Newton Counties.

County	Soil Unit	Soil Name	Soil Description
Jasper	LuB2	Lucas silty clay loam	2-6% slopes, eroded
Jasper, Newton	OaC	Oakville fine sand	6-15% slopes
Newton	MnC2	Miami loam	6-12% slopes
Newton	MnE	Miami loam	15-25% slopes
Newton	OcC2	Octagon loam	6-12% slopes, eroded
Newton	SzB2	Swygert variant-Simonin variant complex	2-6% slopes
Newton	SzC2	Sygert variant-Simonin variant complex	6-15% slopes, eroded

Source: 1988 USDA/SCS Indiana Technical Guide Section II-C for Jasper County; 1987 USDA/SCS Indiana Technical Guide Section II-C for Newton County

These soil types are limited for certain classes of land use, as erosion is a major management concern. Lucas silty clay loam soils (LuB2) are erosion prone, and due to slow permeability, runoff occurs rapidly. Conversely, Oakville fine sand soils (OaC) are well drained soils prone to wind erosion due to droughtiness. Oakville soils are found on ridges and outwash plains that have low water capacity due to their rapid permeability. Miami loam soils (MnC2 and MnE), located on ridges and knolls, are well drained soils with moderate permeability. Their strongly sloping to moderately steep slopes make conservation practices necessary for cultivation.

Slope, shrink-swell potential, and organic matter depletion are the erosion risks associated with the remaining soils listed in Table 6. Octagon loam soils (OcC2) and Swygert variant-Simonin variant complex soils (SzB2 and SzC2) are suited to cultivation only with the usage of Best Management Practices.

Highly Erodible Land

Highly Erodible Land (HEL) is a designation used by the Farm Service Agency (FSA). For a field or tract of land to be labeled HEL by the FSA, at least one-third of the parcel must be situated in highly erodible soils and the soils must be used for production. Unlike the soil survey, these fields must be field checked to ensure the accuracy of the mapped soils types. Farm fields mapped as HEL are required to file a conservation plan with the FSA in order to maintain eligibility for any financial assistance from the USDA. Although much of the Curtis Creek Watershed north of State Road 14 contains highly erodible soil map units, the Curtis Creek Watershed does not contain any tracts of highly erodible land. Many of the highly erodible soils mapped in Jasper County (all of these soil units lie outside of the Curtis Creek Watershed) have been field checked by Natural Resource Conservation Service (NRCS) personnel. Subsequently, the NRCS determined that most of these tracts did not meet the HEL requirements and removed the HEL designation. Newton County has completed a similar process (Julie McLemore, NRCS District Conservationist, personal communication). It is important to note that the FSA will only track HEL if the tract of land is used to produce crops. Parcels of land may be highly erodible but not recorded as such if it is not used for production.

Considerations for On-site Wastewater Disposal Systems

Background Information

Nearly half of Indiana's population lives in residences with private waste disposal systems. As is common in rural Indiana, septic tanks and septic tank absorption fields are utilized for wastewater treatments in the Curtis Creek Watershed. This type of wastewater treatment system relies on the septic tank for primary treatment to remove solids and the soil for secondary treatment to reduce the remaining pollutants in the effluent to levels that protect surface and groundwater from contamination.

A variety of factors can affect a soil's ability to function as a septic absorption field. Seven soil characteristics are currently used to determine soil suitability for on-site sewage disposal systems: position in the landscape, slope, soil texture, soil structure, soil consistency, depth to limiting layers, and the depth to seasonal high water table (Thomas, 1996). The ability of soil to treat effluent (waste discharge) depends on four factors: the amount of accessible soil particle surface area, the chemical properties of soil surfaces, soil conditions like temperature, moisture, and oxygen content, and the type of pollutants present in the effluent (Cogger, 1989).

The amount of accessible soil particle surface area depends both on particle size and porosity. Because they are smaller, clay particles have a greater surface area per unit volume than silt or sand and therefore, a greater potential for chemical activity. However, soil surfaces only play a role if wastewater can contact them. Soils of high clay content or soils that have been compacted often have few pores that can be penetrated by water and are not suitable for septic systems because they are too impermeable. Additionally, some clays swell and expand on contact with water closing even more spaces and pores in the profile. On the other hand, very coarse soils may not offer satisfactory effluent treatment either because the water can travel rapidly through the soil profile. Soils located on sloped land also may have difficulty in treatment of wastewater due to reduced contact time.

Chemical properties of the soil surfaces are also important for wastewater treatment. For example, clay materials all have imperfections in their crystal structure which gives them a negative charge along their surfaces. Due to their negative charge, they can bond cations that have positive charge on their surfaces. However, many pollutants in wastewater are also negatively charged and are not attracted to the clays. Clays can help remove and inactivate bacteria, viruses and some organic compounds.

Environmental soil conditions influence the microorganism community which ultimately carries out the treatment of wastewater. Factors like temperature, moisture, and oxygen availability influence microbial action. Excess water or ponding saturates soil pores and slows oxygen transfer. The soil may become anaerobic if oxygen is depleted. Decomposition processes (and therefore effluent treatment) become less efficient, slower, and less complete if oxygen is not available.

Many of the nutrients and pollutants of concern are removed safely if a septic system is sited correctly. Most soils have a large capacity to hold phosphate. On the other hand, nitrate (the end product of nitrogen metabolism in a properly functioning septic system) is very soluble in soil solution and is often leached to the groundwater. Care must be taken in siting the system to avoid well contamination. Nearly all organic matter in wastewater is biodegradable as long as conditions are right. Bacteria and viruses are much smaller than other pathogenic organisms associated with wastewater and, therefore, have a much greater potential for movement through the soil. Clay minerals and other soil components may absorb them, but retention is not necessarily permanent. During storm flows, they may become resuspended in the soil solution and transported in the soil profile. Inactivation and destruction of pathogens occurs more rapidly in soils containing oxygen because sewage organisms compete poorly with natural soil mircroorganisms, which are obligate aerobes requiring oxygen for life. Sewage organisms live longer under anaerobic conditions without oxygen and at lower soil temperatures because natural soil microbial activity is reduced.

The Curtis Creek Watershed

Soil conditions, such as slow permeability and high water table, coupled with poor design, faulty construction, and lack of maintenance reduce the average life span of septic systems in Indiana to 7-10 years (Jones and Yahner, 1994). Likewise, several onsite systems located in morainal soils in other neighboring areas are known to perform poorly or to have failed completely (Indiana University/Purdue University, 1996). Localized soil-geologic conditions are responsible for most of the problems. In fact, in Wells County in northeast Indiana, the Indiana State Department of Health and the Wells County Health Board have instituted a moratorium on residential development within the Wabash end moraine in an area known as "Buttermilk Ridge", a part of Union Township (Section 14, T28N, R11E). Although no extensive studies have been conducted within the Iroquois Moraine, which extends across a portion of the Curtis Creek Watershed, soil types there share similar compositional characteristics with soils found in the Wabash end moraine.

According to the Newton County Health Department (NCHD), septic system failures throughout Newton County are increasing every year. Most reported failures occur in areas where elevated sand mounds or pump assisted septic systems are required such as the northern portion of the Curtis Creek Watershed (Ruth Ellen Hayward, NCHD Sanitarian, personal communication). Ms. Hayward noted that no septic system failures have been reported in the Curtis Creek Watershed in the last 10 years. Similarly, the Jasper County Health Department (JCHD) has received only one report of septic failure in the past four years (Sandra Parks, JCHD Sanitarian, personal communication). Ms. Parks believes that low population and little growth are the reasons there are so few failures in the Curtis Creek and Iroquois River area. Generally, individuals are hesitant to complain because they most likely have a similar problem and a failing system themselves. When a problem is reported, the JCHD may conduct sampling or dye testing if needed and issue a citation. The homeowner must rectify the situation, or another citation will be issued.

The soil types in the Curtis Creek Watershed are not optimal for septic absorption fields (Smallwood and Osterholz, 1990; Barnes and Osterholz, 1998). Some of the systems are very old, but are well maintained. These systems are not usually replaced unless an individual is selling their residence. Most inspections occur when a new residence is being built; permits for new systems in areas with high water tables, such as Zadog or Maumee soils, will not be issued (Ms. Haywood, NCHD). Ms. Parks notes that most of the growth in Jasper County is business related near the intersection of State Road 114 and Interstate 65. Although, most of the businesses in this area utilize mound septic systems, three sets of businesses maintain wastewater treatment plants. The three treatment plants treat restroom facility and shower wastewater from McDonald's, Burger King, Cooper's Truck Lube Plus, Grandma's Home Cooking Truck Stop, Fireworks Factory Outlet, Trail Tree Inn and Restaurant, and Mid-Continent Inn. (Individual wastewater treatment plants will be discussed in more detail in the Watershed Study section of the report.) The only septic failure in this area is believed to be related to a construction error when the mound system was installed. Actions are being taken to reinstall or replace the faulty portion of the system and to mitigate the impact of the failing mound system.

The NRCS ranks each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: slightly limited, moderately limited, or severely limited. Use of septic absorption fields on soils in the moderately to severely limited categories generally requires special designs, planning or maintenance to overcome the limitations. Table 7 summarizes the soil series located in the study area in terms of their suitability for use as a septic tank absorption field.

TABLE 7. Soil types present in the Curtis Creek Watershed and their suitability for on-site wastewater treatment systems.

County	Name	Symbol	Depth to Water Table	Suitability for Septic Absorption Field
Newton	Ayr loamy fine sand	AyB	>6 ft	Severe: Poor filter
Newton	Ayrmount loamy fine sand	AzA	2.5-4 ft	Severe: Wetness, poor filter
Newton	Barry-Gilford complex	Bh	0.5-1 ft	Severe: Risk of seepage
Newton	Brems loamy sand	BeB, BmB	2-3 ft	Severe: Risk of seepage
Newton	Granby loamy fine sand	Gt	+1-1 ft	Severe: Risk of seepage
Newton	Morocco loamy sand	MuA, Mu	+1-1 ft	Severe: Risk of seepage, poor filter
Newton, Jasper	Oakville fine sand	OaB, OaC	>6 ft	Severe: Risk of seepage, poor filter
Newton	Octagon-Ayr complex	OkB2	>6 ft	Moderate-Severe: Risk of seepage, slope
Newton	Sumarva-Ridgeville-Odell complex	SxA	1-3 ft	Slight
Newton	Zadog-Granby complex	Zg	+1-1 ft	Severe: Risk of seepage
Jasper	Darroch loam	Dc	1-3 ft	Severe: Risk of seepage
Jasper	Darroch, till substratum-Odell complex	Dg	1-3 ft	Severe: Risk of seepage
Jasper	Markton-Aubbeenaubbee complex	MaB	1-3 ft	Severe: Risk of seepage
Jasper	Martinsville fine sandy loam	McB	>6 ft	Slight
Jasper	Metea fine sandy loam	MkB	>6 ft	Severe: Poor filter
Jasper	Oakville sand	ObB	3-6 ft	Severe: Risk of seepage, poor filter
Jasper	Papineau sandy loam	Pa	1-3 ft	Severe: Wetness, percs slowly
Jasper	Rensselaer loam	Re	+0.5-1 ft	Severe: Ponding
Jasper	Rensselaer fine sandy loam	Rs	+0.5-1 ft	Severe: Ponding
Jasper	Rensselaer, till substratum-Wolcott complex	Rw	+0.5-1 ft	Severe: Ponding
Jasper	Sloam silt loam	So	0-1 ft	Severe: Flooding, wetness
Jasper	Strole clay loam	St	1-2 ft	Severe: Wetness, percs slowly
Jasper	Whitaker fine sandy loam	Wt	1-3 ft	Severe: Wetness

Source: Smallwood and Osterholz, 1990; and Barnes and Osterholz, 1998

Of the soil types present in the study drainage, only the Sumarva-Ridgeville-Odell complex (SxA) and the Martinsville fine sandy loam (McB) are rated as slightly limited for usage as septic leachate field. The Octagon-Ayr complex (OkB2) is moderately limited for treatment as long as it is situated on slopes of less than 6%. Systems installed on slopes steeper than 6% are rapid drained, resulting in improper leach field functioning; risk of groundwater and nearby surface water contamination is high in these situations.

The remaining 20 soil types are severely limited for use as septic system substrate and are generally not conducive to the satisfactory operation of conventional on-site treatment systems. The Darroch loam (Dc), Darroch, till-substratum-Odell (Dg), Barry-Gilford (Bh), Zadog-Granby (Zg), and Markton-Aubbeenaubbee (MaB) complexes; Brehms loamy sand (BeB, BmB); and Whitaker fine sandy loam (Wt) tend to be wet, poorly drained soils. Papineau sandy loam (Pa) and Strole clay loam (St) tend to be wet, poorly drained soils with slow permeability. Oakville sand (ObB) and fine sand (OaB, ObB), Morocco loamy sand (Mu, MuA), and Grandy (Gt) and Ayrmount (AzA) loamy fine sands are also poorly drained soils with poor filtering capacity. Sloam silt loam (So) is poorly drained to the point of flooding. High water tables especially during wet seasons can cause soil saturation and even ponding. Characteristic wetness can lead to anoxic conditions and improper treatment within leach fields. It is recommended that systems be installed with perimeter surface drains to lower the water table, installed with an enlarged leach field to offset slow permeability, and constructed when the soil is dry to avoid soil sealing and compaction.

Soils belonging to the Rensselaer series (Re, Rs, and Rw) are severely compromised for septic effluent treatment. The water table is often within one foot of the surface, and because the water table is often at the same level as surface water features (lakes and streams), achieving proper septic field drainage may be impossible.

Metea fine sandy loam (MkB) and Ayr loamy fine sand (AyB) are well-drained, highly permeable soils. All soil, subsoil, and underlying material layers are highly permeable. These soils are severely limited for effluent treatment because drainage time is too rapid to allow for filtration. Poor filtration and treatment may compromise ground water quality.

Many of the soil types in the study watershed have severe limitation for septic suitability (Table 7). Geologic conditions in many parts of the diffuse moraine deposits are not likely to promote satisfactory septic system function resulting in surface and groundwater pollution. Although no septic inspections or sampling were conducted as part of this study, stream water quality sampling does not rule out improperly functioning systems as a possible cause of surface water pollution in the watersheds particularly in samples were *E. coli* concentrations during storm water runoff exceeded 5,000 col/100 ml. However, manure spreading for fertilizer is a common practice in the study area; runoff from fields where manure has recently been spread can result in elevated *E. coli* levels as well.

To address water quality issues associated with the use of septic systems, residential development that rely on septic systems for treatment of wastewater should proceed with caution, especially in soils unsuited for conventional septic treatment systems. Competent soil scientists that are familiar with conditions should evaluate potential development sites for evidence of poor water movement, soil development, or filtering ability. Alternative technology, like the mound system, the at-grade system, the pressure-dosed system, or wastewater wetland may provide a solution in soils that are unsuitable. Some soils may be suitable for alternating field technology which requires that a second field be available to accept effluent while the primary field “rests”. Enlarged septic fields should be installed to increase the area of absorption. It is important to note, however, that some soils are too wet, too shallow, too impermeable, too steep, or too well-drained for any type of system.

Once the proper technology has been installed, proper maintenance is very important. Depending on the size of the system and the loading to it, systems should be cleaned every 2 to 5 years. Property owners should divert surface runoff away from absorption fields, keep a cover of vegetation over the field, and keep foot and vehicular traffic over the field to a minimum. Pressure on septic systems can also be reduced by common water conservation practices like shorter showers and less flushing and rinsing, within reason.

Soil Summary

The type of soils in a watershed and the land uses practiced on those soils can impact the quality of the water in the watershed. Soil erosion contributes sediment to waterways reducing water quality downstream, degrading aquatic habitat, and interfering with recreational uses. Nutrients attached to eroded soils fertilize and increase aquatic production. Additionally, soil eroding from the landscape accumulates in ditches and drainageways necessitating costly dredging maintenance projects. Not only does the sediment hinder water conveyance, it also provides a nutrient-rich substrate for rooted aquatic plant growth. Nutrients and nutrient-rich sediment can promote the growth of nuisance levels of algae and plants downstream in other waterbodies. Consequently, conservation methods and best management practices (BMPs) should be utilized when soils are disturbed in these areas. This includes residential development and farming practices in highly erodible soils.

Soil type should also be considered in siting septic systems. Some soils do not provide adequate treatment for septic tank effluent. Much of the land in the study watersheds is mapped in soils that rate as severely limited or generally unsuitable for use as septic tank absorption fields. This is typical for much of Indiana, as research by Dr. Donald Jones suggests that 80% of the soils in Indiana are unsuitable for wastewater treatment (Grant, 1999).

Pollution from septic tank effluent can affect waterways, the life the waterways supports, and the users of these waterways in a variety of ways. It can contribute to eutrophication (overproduction) and water quality impairment of creeks and other waterbodies in the watershed. In addition, septic tank effluent potentially poses a health concern for users of both surface and groundwater in the watershed. Swimmers, anglers, or boaters that come in contact with contaminated water may be exposed to waterborne pathogens. This is an issue of concern for Curtis Creek, its tributaries, and its receiving waterbody, the Iroquois River, since according to Indiana State statutes, these waterbodies should support contact recreation as a beneficial use (IDEM, 2000; IAC, 2000). Fecal contaminants can be harmful to humans and cause serious diseases, such as infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illness. Additionally, nitrogen and pathogens may also leach into the groundwater compromising drinking water.

Land Use

Table 8 and Figure 5 present land use information for the Curtis Creek Watershed. Land use data was obtained from the USGS EROS Land Use Data coverage. The EROS Land Use Data coverage was last corrected to reflect current conditions during December 1998. As a part of this study, the EROS data was checked with recent aerial photography and in some areas was field checked and corrected to reflect watershed conditions as of 2002. Land use data for each subwatershed is presented in Appendix 1.

TABLE 8. Land use in the Curtis Creek Watershed.

	Area (acres)	Area (ha)	Percent of Watershed
Agriculture Row Crop	19,349	7,830.4	72.82%
Agriculture Pasture/Grasses	2,971	1,202.3	11.18%
Deciduous Forest	2,884	1,167.1	10.85%
Grassland/Herbaceous	419	169.6	1.58%
Woody Wetlands	352	142.5	1.32%
Evergreen Forest	225	91.1	0.85%
Recreation/Park Land	120	48.6	0.45%
High Intensity Commercial	103	41.7	0.39%
Low Intensity Residential	60	24.3	0.23%
Emergent Herbaceous Wetlands	51	20.6	0.19%
Open Water	22	8.9	0.08%
High Intensity Residential	8.0	3.2	0.03%
Agriculture Small Grains	6.6	2.7	0.02%
Mixed Forest	0.8	0.3	0.00%
Bare Rock/Sand/Clay	0.4	0.2	0.00%
	26,572	**10,753**	**100%**

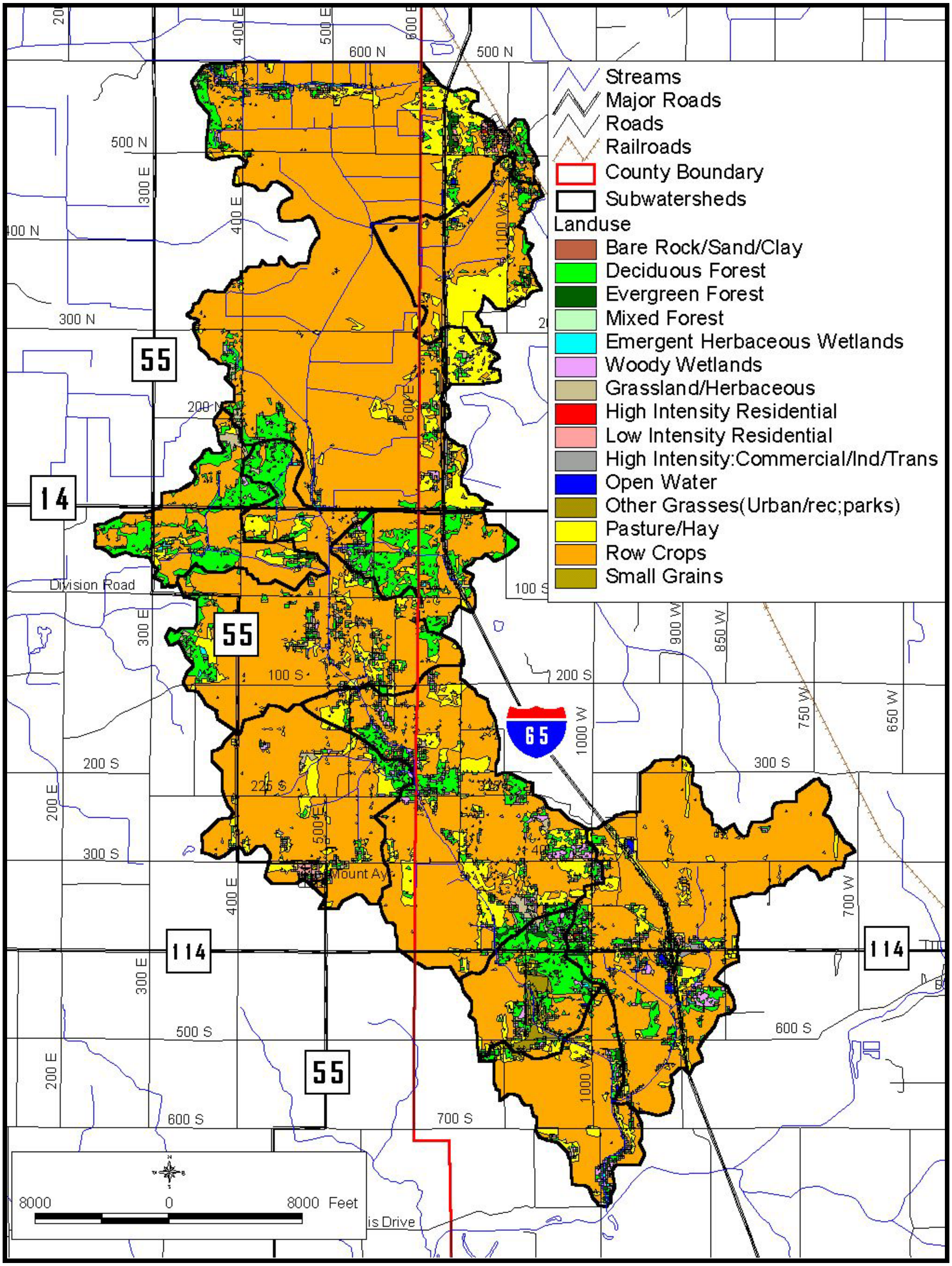


FIGURE 5. Land use in the Curtis Creek Watershed.

Approximately 84% of the watershed is used for agricultural purposes, including cropland, pasture, and small grain production. This percentage is slightly higher than that estimated by the U.S. Census of Agriculture (1997) for Jasper (79%) and Newton (80%) Counties. Because the watershed is located in a rural area, more land is used for cultivation than is average for the counties. Table 9 contains more detailed U.S. Census of Agriculture (1997) data for the two counties.

TABLE 9. Detailed U.S. Census of Agriculture data for Newton and Jasper Counties.

County	# of Farms	Land in Farms (acres)	Total Land (acres)	Percent of County Farmed
Jasper	618	282,915	359,321	79%
Newton	381	207,315	258,080	80%

Source: U.S. Census of Agriculture, United States Department of Commerce (1997).

Soybeans, corn, small grains, and forage are the major crops grown in Jasper and Newton Counties. Although exact percentages of each crop were not recorded for the study watershed, between 39 and 41% of the agricultural fields in the counties were planted with soybeans and 49-56% in corn in 2001; in 2002 between 38 and 45% of fields were planted with soybeans while 45-51% were planted with corn (Purdue University Cooperative Extension Service, 2002). It is likely that the study watersheds closely mirror these percentages. Table 10 contains more detailed information regarding percentage and acreage of Newton and Jasper County fields used to produce different crops and commodities and estimated numbers of cattle in 2001. Note that Newton County and Jasper County rank second and fourth, respectively, in the state for dairy cattle production.

TABLE 10. Percent and acreage of Jasper and Newton County fields with indicated present crop for year 2002. Percentages are taken from a field sampling of points along transects across the counties. No data are available for percent or acreage of land in permanent pasture. The number of beef cattle, dairy cattle, and total cattle in the counties in 2002 are also given. The last column provides production rank for each county in the state for each of the commodities.

Crop/Commodity	Percent or Number	Acreage of Land	Rank in State
Jasper County			
Soybeans	39%	103,367	10
Corn	56%	149,835	3
Small Grains	0.5%	1,422	58
Hay/Forage	3%	7,112	75
Beef Cattle	1,600		53
Dairy Cattle	7,200		4
Total Cattle	15,600		14
Newton County			
Soybeans	41%	81,036	27
Corn	49%	97,160	22
Small Grains	1%	2,067	67
Hay/Forage	4%	7,442	41
Beef Cattle	1,400		58
Dairy Cattle	14,800		2
Total Cattle	18,600		11

Source: Mark Evans, Purdue Cooperative Extension Agency; U.S. Census of Agriculture 2002 Projections.

Prime farmland is one of several land types classified and recognized by the USDA. Prime farmland is land that is best suited for crops. The land is used for cultivation, pasture, woodland or other production, but it is not urban land or water areas. This type of land produces the highest yields with minimal inputs of energy and economic resources. Farming it results in the least damage to the environment. Therefore, when possible, the optimal land use strategy places industrial and residential development on the marginal lands while keeping prime farmland available for production. According to the USDA soil surveys of Jasper and Newton Counties, approximately 57-60% of the acreage in the general area meets prime farmland requirements; the majority of the land in the southern portion of the Curtis Creek Watershed is classified as prime farmland.

"A recent trend in land use in some parts of the county has been the loss of some prime farmland to industrial and urban uses. The loss of prime farmland to other uses puts pressure on marginal lands, which generally are more erodible, wet or droughty, and less productive and cannot be as easily cultivated." (Barnes and Osterholz, 1998). Cultivation of more marginal land also results in more damage to the environment. Although the Curtis Creek Watershed is not undergoing rapid urbanization, some new development was noted during the windshield tour (which will be discussed in more detail later). This type of change in land use will have obvious impacts on water quality, especially if it results in more farming of marginal land. Again, careful land use and development planning can minimize the need to produce crops on marginal land.

In general, row crop agriculture dominates land use throughout the subwatersheds (Figure 6). The Golf Course Subwatershed is the most diverse with respect to different types of land use, while the Headwaters Subwatershed is the least diverse. The Headwaters and Yeoman Ditch Subwatersheds contain the only notable acreages of urban land due to the municipality of Fair Oaks and growth near the intersection of State Road 114 and Interstate 65. Based on percent of the total acreage, the Kosta Ditch and Yeoman Ditch Subwatersheds possess the largest percentage of urban areas (Figure 6).

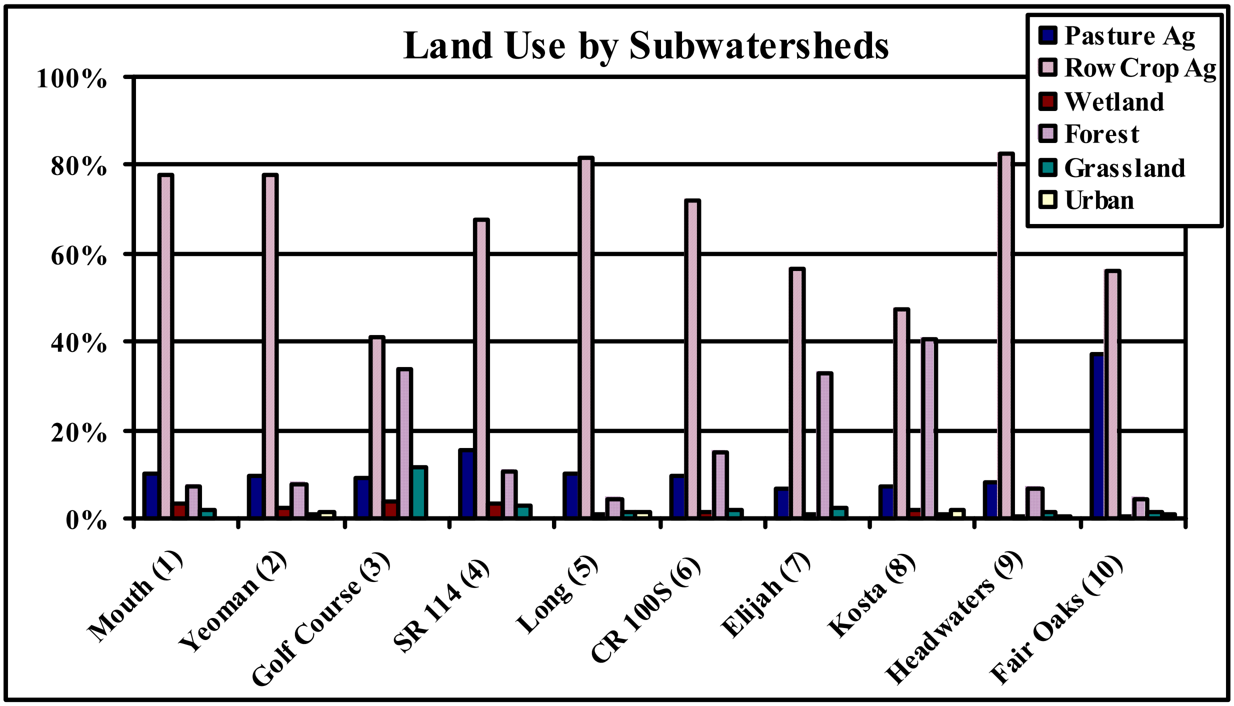


FIGURE 6. Percent of total watershed area used for the broad land use categories: pasture agriculture, row crop agriculture, urban, wetland, forest, and grassland.

Aside from agricultural uses, forests, grasslands, and wetlands represent the only other notable land use within the study watershed (Figures 5 and 6). In some cases like along the mainstem of Long Ditch in Subwatershed 5, these forested and wetland natural areas directly border stream segments. Not only do these forest areas and wetlands help moderate stream water temperature and velocity, they also offer water storage capacity and sediment and nutrient filtration. Figure 7 further classifies the wetlands based on National Wetland Inventory (NWI) data. According to the NWI data, most wet areas are palustrine, emergent wetlands (Table 11). Due to the small remaining concentration of forest, grassland, and wetland land use (only about 15% of the watershed), their protection is merited. Farmers should also be encouraged to route drainage tiles toward specified treatment wetlands or filter areas. Riparian buffer area filtration is drastically reduced when drainage tiles completely bypass them, carrying drainage water directly to the ditch.

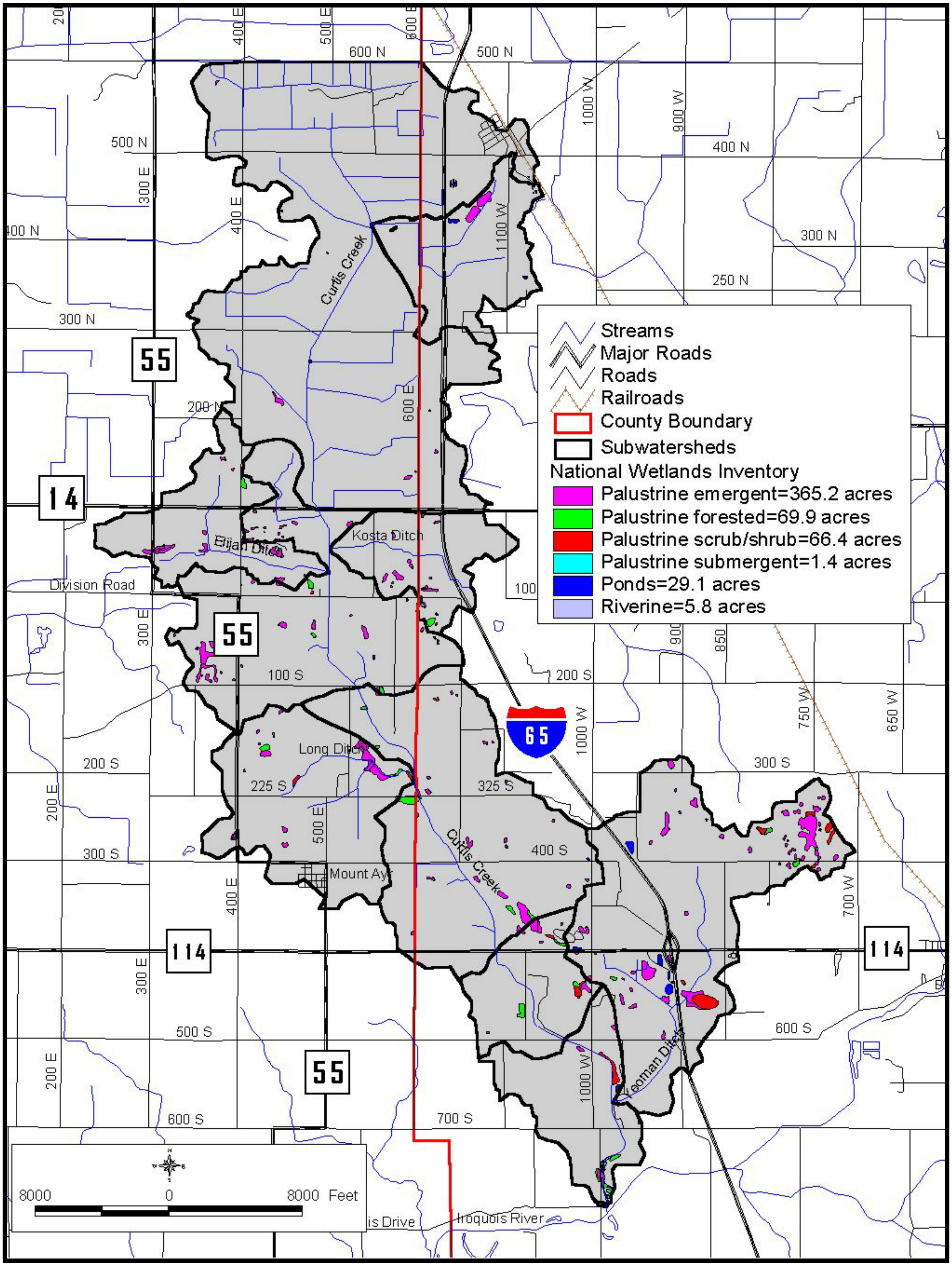


FIGURE 7. National Wetland Inventory (NWI) map.

TABLE 11. National Wetland Inventory (NWI) data for the Curtis Creek Watershed.

Wetland Type	Area
Palustrine Emergent	365 acres (147.7 ha)
Palustrine forested	70 acres (28.3 ha)
Palustrine scrub/shrub	66 acres (26.7 ha)
Palustrine submergent	1 acres (0.4 ha)
Ponds	29 acres (11.7 ha)
Riverine	6 acres (2.4 ha)
Uplands	26,035 acres (10,536 ha)

Few tracts of pastureland directly border streams in the watershed (Figure 5). The State Road 114, Long Ditch, and Elijah Ditch Subwatersheds contain some pastureland tracts that border Curtis Creek and its tributaries. When pastured livestock is allowed direct access to streams, pastureland use is closely coupled with riparian area degradation and increased soil, nutrient, and bacterial runoff. Efforts should be made to exclude livestock from waterways in these critical areas.

Other land uses are very negligible within the Curtis Creek Watershed. Open water, consisting of small ponds, occupies 0.08% of the watershed. Only 0.64% of the watershed has undergone urban development. The remaining land uses and coverage compose a meager 0.45% including non-vegetated developed land and recreation or park land.

Agricultural Best Management Practices (BMPs)

Approximately 73% of the Curtis Creek Watershed is utilized for agricultural row crop production. This land use, particularly on highly erodible soils and in other environmentally sensitive areas, can have an impact on water quality downstream. Runoff from farm fields can contain a variety of pollutants including nutrients (nitrogen and phosphorus), herbicides, pesticides, sediment, and bacteria (*E. coli*). According to the National Research Council (1993), non-point source pollution by contaminants in agricultural runoff is a major cause of poor surface water quality in the USA. In addition, the development of land for agricultural purposes involved draining low wet areas using tiles and ditches. This has decreased the storage capacity of the land and increased peak flows in streams and channels in the watersheds. An increase in both the volume and velocity of peak flows typically leads to increases in streambed and bank erosion and ultimately increases in sediment and sediment-associated particle loading to the receiving waterbody.

Several programs and Best Management Practices (BMPs) have been developed to address non-point source pollution associated with agriculture. BMPs may be structural or managerial in nature (Osmond et al., 1995). Filter strips, riparian buffer strips, grassed waterways, and use of other erosion control structures are examples of structural practices, while rotational grazing, conservation tillage, and nutrient and pesticide management are managerial BMPs. Each BMP is helps ensure healthy and productive farmland while protecting sensitive areas on the landscape. Programs and BMPs that are currently in use in the study watershed or that could potentially be used more frequently or consistently are discussed below.

The Conservation Reserve Program

The Conservation Reserve Program (CRP) is the single, largest environmental improvement program offered by the federal government. The program arose out of concerns raised by USDA studies conducted in the early 1980s showing that the nation's cropland was eroding and losing soil at a rate of 3 billion tons per year (USDA, 1997). The CRP provides volunteer participants with an annual per-acre rent and a lump sum payment equal to 50% of the cost of establishing permanent land cover. In return, participants are required to retire the cropland from production for 10-15 years.

Removing land from production and planting it with vegetation has a positive impact on water quality within the given watershed. In a review of Indiana lakes sampled from 1989 to 1993 for the Indiana Clean Lakes Program, Jones (1996) showed that lakes within ecoregions reporting higher percentages of cropland in CRP had lower mean trophic state index (TSI) scores. A lower TSI is indicative of lower productivity and better water quality.

The New Conservation Reserve Program established in 1997 is targeted at the most environmentally sensitive land into the program. Congress capped the program at 36.4 million acres, meaning that only about 15% of eligible cropland could be enrolled. Land is evaluated and scored for environmental benefit, including: wildlife habitat enhancement, water quality benefits, reduced erosion, long-term retention benefits, air quality benefits, land's location in a Conservation Priority Area, and cost of enrollment per acre. The CRP attempts to maximize conservation and economic benefits by focusing on highly erodible land, riparian areas, cropped wetlands, and cropland that contains wetlands that are not farmed.

CRP in the Study Watershed

Landowners currently utilize a variety of conservation practices in the study watershed. Figure 8 shows the locations of cropland enrolled in the CRP. Instead of farming the tracts, landowners have installed filter strips, grassed waterways, and wildlife set-asides. Table 12 contains acreages of land enrolled in the CRP within the Curtis Creek Watershed. The Kosta Ditch Subwatershed contains the largest percentage, 4.5% (46.2 ac or 18.7 ha), of CRP within the Curtis Creek Watershed. In total, approximately 10% of the Curtis Creek Watershed, or 162.8 acres, is set aside in the Conservation Reserve Program. Tracts of land enrolled in the CRP and not drawn to scale in Figure 8; nonetheless, these acreages were used to calculate relative percentages of each of the subwatersheds enrolled in the CRP.

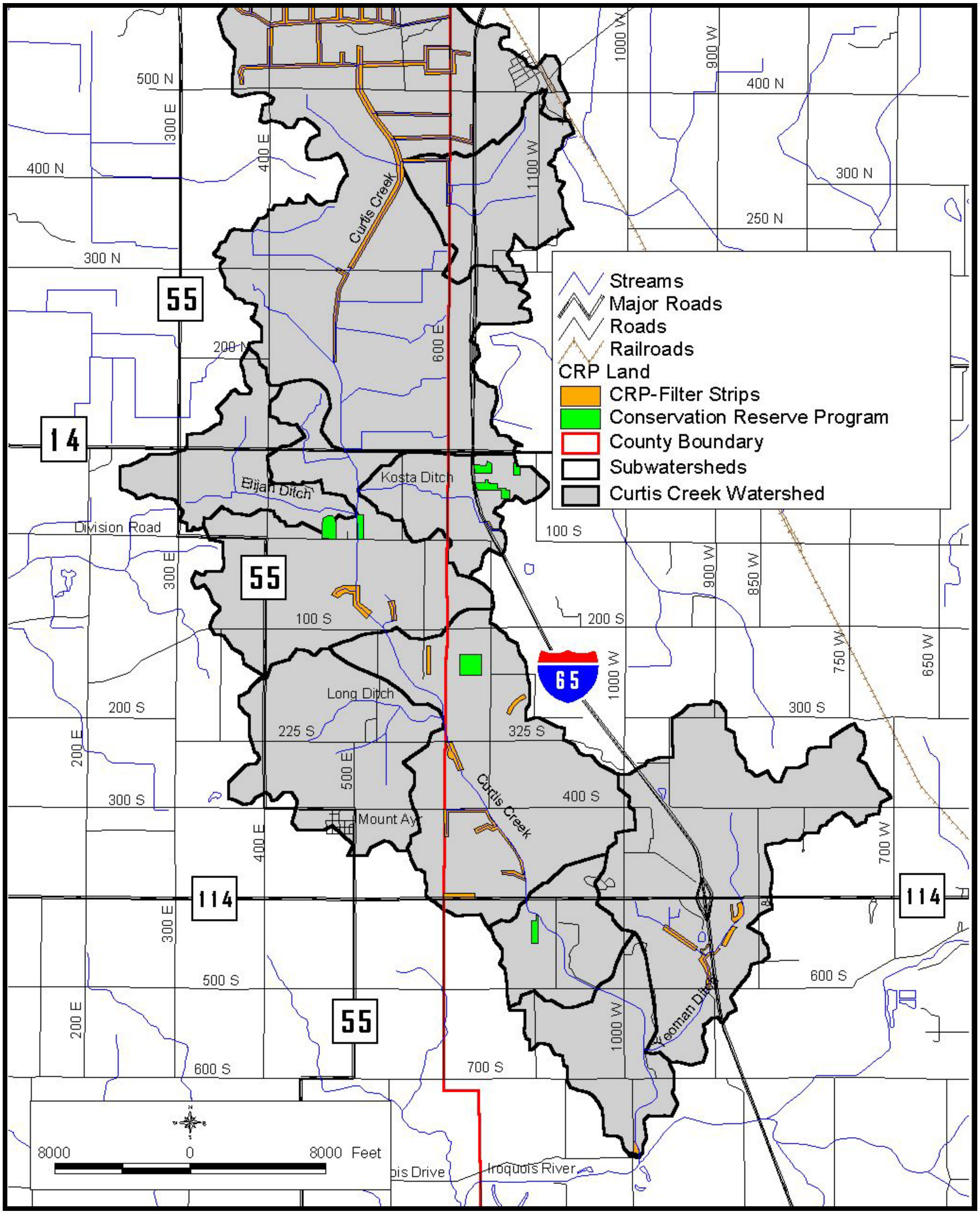


FIGURE 8. Conservation Reserve Program tracts.

TABLE 12. Acreages of land enrolled in the CRP by subwatershed.

Subwatershed	Acres	Hectares	Percent of Watershed
Curtis Creek Mouth Subwatershed	7.2	2.9	0.57%
Yeoman Ditch Subwatershed	11.8	4.8	0.31%
Golf Course Subwatershed	0.0	0.0	0.00%
State Road 114 Subwatershed	17.3	7.0	0.47%
Long Ditch Subwatershed	0.0	0.0	0.00%
County Road 100 South Subwatershed	11.1	4.5	0.36%
Elijah Ditch Subwatershed	7.0	2.8	0.54%
Kosta Ditch Subwatershed	46.2	18.7	4.49%
Headwaters Subwatershed	33.0	13.4	0.42%
Fair Oaks Subwatershed	29.2	11.8	2.35%
Total	**162.8**	**65.9**	**9.51%**

Source: Farm Service Agencies of Jasper and Newton Counties.

Conventional Structural Conservation Practices

Continuous sign-up is permitted through the CRP for special high-priority conservation practices that lead to significant environmental benefits. These practices are structural in nature and are specially designed to protect and enhance wildlife habitat, improve air quality, and improve waterway condition. These conservation practices and relevant research involving their use are discussed in more detail below.

Filter Strips

A filter strip is an area of grass or other permanent vegetation used to reduce sediment, organic material, nutrients, pesticides, and other contaminants from runoff. Filter strips slow the velocity of water, allowing settling of suspended particles, infiltration of runoff, adsorption of pollutants on soil and plant surfaces, and uptake of soluble pollutants by plants. Slower runoff velocities and reduced flow volumes lead to decreased downstream erosion.

A modeling study by Texas A&M University suggests that if filters were properly installed in all appropriate locations, sediment delivery to rivers and lakes could be reduced by two-thirds (National Conservation Buffer Council, 1999). Preventing sediment delivery to streams has important and significant economic ramifications. According to a study by the Ohio State University Extension Service, a 25% decrease in the amount of sediment entering waterways in the state would save $2,700,000 in water treatment costs per year (Leeds et al., 1997). The cost of dredging sediment out of these waterways was estimated at $1,500,000 per year for the state of Ohio. Additionally, buffer strips have been associated with healthier aquatic communities (Wiegel et al., 2000).

Typically, filter strips are planted on cropland at the lower edge of a field or adjacent to waterways. They are most effective when receiving shallow, uniform flow rather than concentrated runoff localized in channels or gullies. The Natural Resources Conservation Service (NRCS) recommends minimum filter strip widths be based on intended purpose of the area (NRCS, 2000). The minimum length across which water should flow prior to entering the waterbody is set at 20 ft (6 m), but the minimum can be increased to 30 ft (9 m) based on sediment, particulate organic matter, and sediment-adsorbed contaminant loads in runoff. The average watershed slope above the filter strip must be greater than 0.5% but less than 10%. The NRCS standard is site-specific with plans and specifications required for each field site where a filter strip will be installed. It is important to keep in mind that effective filter strip width is also dependent on the amount of land draining into the filter. Ratios of the field drainage area to the filter area should be no greater than 50:1. Based on a survey of more than 2,700 CRP sites in the U.S., the ratio averaged approximately 3:1 (Leeds et al., 1993).

A wide variety of vegetation types have been used for planting filter strips. The ideal plant or combination of plants would possess the following characteristics: native to Indiana; sod-forming; palatable as forage; somewhat cool season so as to grow early in spring when most runoff events occur; hardy, rapidly growing, tolerant of nutrient-poor conditions so as to not need fertilization; able to remain standing throughout the winter providing shelter for wildlife; and economical/affordable.

The use of plants native to Indiana is ecologically the most desirable alternative. (Please see the NRCS Conservation Practice Standard Code 393 for specifics and requirements regarding vegetation planting within filter strips (NRCS, 2000).) Advantages of planting native vegetation are that: 1.) native species possess extensive rooting structures that hold soil and reduce erosion (Figure 9 depicts rooting depths of several native grass species); 2.) many types can be hayed for forage use, and in fact big bluestem and Indian grass as highly palatable for forage (Clubine, 1995); 3.) natives are hardy and able to withstand various hydrologic regimes; 4.) natives have low maintenance requirements and cost less over the long-run due to natural re-seeding processes and hardiness; 5.) natives possess lower nutrient requirements and therefore do not require costly fertilization which can further impair water quality; 6.) native plants provide wildlife habitat by remaining standing through the winter; 7.) native wildflowers are beautiful, and their seeds can be added to mixes for aesthetic value; and 8) some legume species like roundhead lespedeza, prairie clover, lead plant, and tickclover are quite resilient to livestock grazing (Clubine, 1995).

Some disadvantages of establishing native herbaceous vegetation in filter strips also exist because: 1.) most native grasses are warm season (except for red top and Virginia wildrye) and may not offer optimal nutrient uptake in early spring when many runoff events occur; 2.) some species have been reported to be difficult to establish and may take years for full stand development (Leeds et al., 1993); 3.) native wildflower plants and other forbs can be quite susceptible to herbicides used in crop production; 4.) many natives are quite expensive to produce (see tables below); and 5) some native legume species like Illinois bundleflower have been shown to be susceptible to grazing (Clubine, 1995).

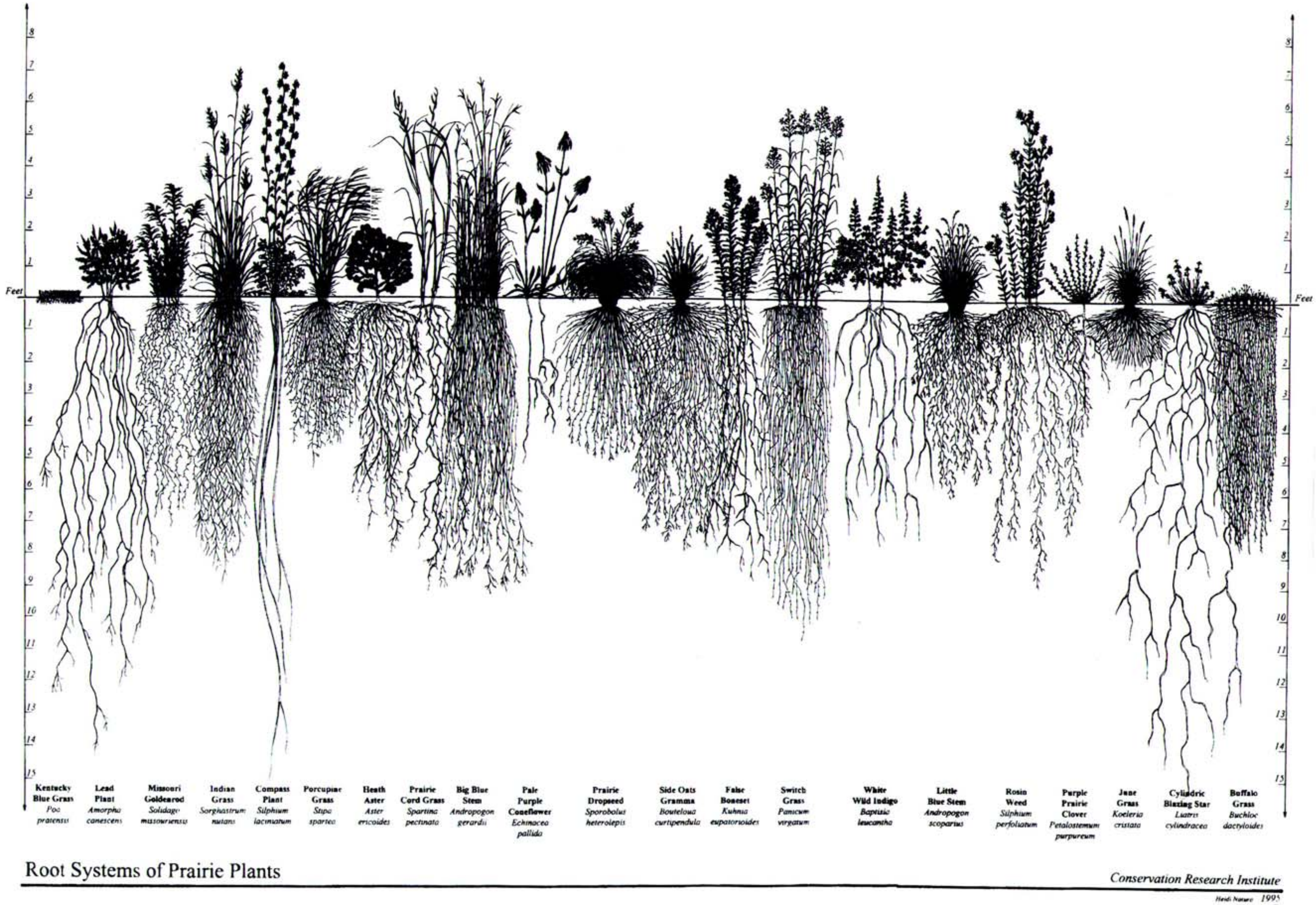


FIGURE 9. Rooting Depths of Native Grasses and Forbs.

Tables 13-19 present lists of recommended native cool season grasses, legumes, and wildflowers. Information is also presented on species that are considered less than desirable as filter strip vegetation. Five different recommended mixes are provided along with seeding rates in lbs/acre and approximate costs according to the February of 2001 price listing of Sharp Bros. Seed Company of Missouri and the J.F. New Native Plant Nursery 2001 Wholesale Catalog. 2001 prices are listed to provide an idea of the cost associated with these seed mixes. Seed prices may have changes since 2001; therefore, these and other seed companies should be consulted prior to installation. Mixes should be chosen based on the landowner's specific application and available finances. Table 20 lists vegetation types that should not be used due to severe limitations. It is important to remember that a filter strip or conservation easement planted with any vegetation type is better than not having the easement at all. Even if optimal mixes are not chosen or utilized, an individual's participation in a set-aside program will have positive effects for water quality.

It is also necessary here to caution landowners who receive federal and/or state monies for planting vegetation. Certain programs may require special seeding mixtures. For example, CRP filter strips must be planted as per Tables 1 and 2 in the NRCS Conservation Practice Standard Code 393. The following eight tables give recommendations for landowners who may be purchasing their own seed or have received cost-share monies from programs that are more flexible with respect to seeding requirements.

TABLE 13. Recommended native cool season grass species and seeding rates (lbs/acre) for filter strip planting.

Species	Seeding Rate	Price/lb
Red top	4 lbs/acre	$3.40
Virginia wildrye	4 lbs/acre	$6.90

Note: If seeding both together, use 2.5 lbs/acre of each.
Source: Sharp Bros. Seed Company of Missouri, February 2001.

TABLE 14. Recommended native legume species and seeding rates (lbs/acre) for filter strip planting with respective prices/lb.

Species	Seeding Rate	Price/lb
Roundhead lespedeza	0.25 lbs/acre	$98.00
Partridge pea	0.25 lbs/acre	$16.10
Illinois bundleflower	0.25 lbs/acre	$6.90
Purple prairie clover	0.25 lbs/acre	$23.00

Note: These forbs should be sown with native grass seed mixture.
Source: Sharp Bros. Seed Company of Missouri, February 2001; J.F. New Native Plant Nursery 2001 Wholesale Catalog.

TABLE 15. Recommended native wildflower species for filter strip planting with respective prices/lb.

Species	Price/lb
Black-eyed susan	$22.50
Lanceleaf coreopsis	$27.00
White prairie clover	$137.50
Ashy sunflower	$55.50
Pale purple coneflower	$108.90
Pitcher sage	$72.00
Compass plant	$99.00
Rosinweed	$74.25
Leadplant	$99.00
Purple coneflower	$29.70
Rattlesnake master	$99.00

Note: These native wildflowers can be seeded in small quantities (<0.25 lbs/acre) along with recommended seeding of native grasses.
Source: Sharp Bros. Seed Company of Missouri, February 2001; J.F. New Native Plant Nursery 2001 Wholesale Catalog.

TABLE 16. Optimal seed mix for filter strip seeding. This mix is considered optimal based on water quality and soil protection benefits, habitat management benefits, and economy/affordability. Six species are included plus a mix of wildflowers for a total seeding rate of 5.25 lbs/acre.

Species	Seeding Rate
Big bluestem	1.3 lbs/acre
Indiangrass	1.5 lbs/acre
Little bluestem	1.5 lbs/acre
Sideoats grama	0.5 lbs/acre
Switchgrass	0.2 lbs/acre
Mixed wildflowers	0.25 lbs/acre
TOTAL PRICE	**$64.25/acre**

Note: Virginia wildrye and red top can be seeded with the above mixture to increase cool season growth. Virginia wildrye should be seeded at 1 lb/acre and red top at 2 lbs/acre.
Source: J.F. New Native Plant Nursery 2001 Wholesale Catalog.

TABLE 17. Economy mix for filter strip seeding. This mix offers native grass species at a more affordable cost. Only three species are included for a total seeding rate of 4.0 lbs/acre.

Species	Seeding Rate
Big bluestem	1.0 lbs/acre
Indiangrass	1.0 lbs/acre
Little bluestem	2.0 lbs/acre
TOTAL PRICE	**$49.90/acre**

Note: Virginia wildrye and red top can be seeded with the above mixture to increase cool season growth. Virginia wildrye should be seeded at 1 lb/acre and red top at 2 lbs/acre.
Source: J.F. New Native Plant Nursery 2001 Wholesale Catalog.

TABLE 18. Ultra economy mix for filter strip seeding. This mix offers only one native grass species at the most affordable cost. It is recommended that Virginia wildrye and red top be seeded with the switchgrass to increase species and habitat variety and to increase cool season growth in the filter strip.

Species	Seeding Rate
Switchgrass	5 lbs/acre
TOTAL PRICE	**$15-20 lbs/acre depending on variety selected**

Source: J.F. New Native Plant Nursery 2001 Wholesale Catalog.

TABLE 19. Wildlife habitat management seed mix for filter strip planting or for other areas where managing prairie-type habitat for wildlife is desirable. The total cost for seeding of one acre (51.5 lbs.) is $450 (J.F. New Native Plant Nursery Wholesale Catalogue, 2001). The temporary grasses serve only to stabilize soils and provide habitat until the permanent, perennial grasses fully develop.

Species	Seeding Rate
Permanent Grasses	5 lbs/acre
Big bluestem	
Little bluestem	
Sideoats grama	
Virginia wildrye	
Switchgrass	
Temporary Grasses	44 lbs/acre
Seed oats	
Annual rye	
Timothy grass	
Native Forbs	2.5 lbs/acre
Butterfly milkweed	
New England aster	
Partridge pea	
Sand coreopsis	
Purple coneflower	
False sunflower	
Rough blazing star	
Wild lupine	
Yellow coneflower	
Black-eyed susan	

Source: J.F. New Native Plant Nursery 2001 Wholesale Catalog.

TABLE 20. Plant species that are generally not good candidates for use in filter strips and reasons for their unsuitability. The reasons listed in the table represent the opinions of J.F. New and Associates, Inc. and are based on scientific literature, experience and observation, and rooting physiology information.

Species	Reasons for Unsuitability
Birdsfoot trefoil	poor rooting structure with little ability to stabilize soil
Smooth brome	poor rooting structure with little ability to stabilize soil
Fescue	poor rooting structure with little ability to stabilize soil
Japanese millet	poor rooting structure with little ability to stabilize soil
Orchardgrass	poor rooting structure with little ability to stabilize soil
Reed canarygrass	poor rooting structure with little ability to stabilize soil; invasive; excludes other more beneficial vegetation; no wildlife habitat benefit
Crownvetch	poor rooting structure with little ability to stabilize soil; invasive
Kentucky bluegrass	very shallow root system; invasive; excludes other more beneficial vegetation; no wildlife habitat benefits
Perennial rye	invasive; excludes other more beneficial vegetation
Red clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive
White clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive

Filter strip effectiveness has been the subject of voluminous recent research. Most research indicates that filter strips are effective at sediment removal from runoff with reductions ranging from 56-95% (Arora et al., 1996; Mickelson and Baker, 1993; Schmitt et al., 1999). Most of the reduction occurs within the first 15 feet (4.6 m). Smaller additional amounts are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus predominately associates with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrient concentration like those of nitrate, dissolved phosphorus, atrazine, and alachlor, although reductions of up to 50% have been documented (Conservation Technology Information Center, 2000). Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Filter strip age is an additional factor of importance for effective function. Schmitt et al. (1999) found older grass plots (25 yr-old) to be more effective filters than recently planted ones (2 yr-old). A longer amount of time was required for runoff to reach the outfall of the older plots, suggesting that a strip's ability to slow runoff and filter pollutants increases with age.

Filter strips are effective in reducing sediment and nutrient runoff from feedlot or pasture areas as well. Olem and Flock (1990) report that buffer strips remove nearly 80% of the sediment, 84% of the nitrogen, and approximately 67% of the phosphorus from feedlot runoff. In addition, they found a 67% reduction in runoff volume. However, it is important to note that filter strips should be used as a component of an overall waste management system and not as a sole method of treatment.

Filter strips, like all conservation practices, require regular maintenance in order to remain effective. Maintenance consists of: 1) frequent inspection of the project filter strip after large storm events; 2) repairing and reseeding of any areas where erosion channels develop; 3) reseeding of bare areas; and 4) mowing and removing hay to maintain moderate vegetation height. Filter strip vegetation should not be cut lower than 6 inches. To avoid destruction of wildlife nesting areas, delay mowing until after mid-July; 5) controlling trees, brush, and noxious or invasive weeds within the filter; 6) applying fertilizer and lime at rates suggested by regular soil testing.

Riparian Buffers
In many ways similar to filter strips, riparian buffers are streamside plantings of trees, shrubs, and grasses intended to intercept pollutants before they reach a river or stream. Although comparisons reveal that riparian buffers are no better than grassed strips at retaining nutrients and sediment, they offer shade and cover to the stream, thereby providing valuable fish and wildlife habitat (Daniels and Gilliam, 1996). Due to their deeper rooting systems, riparian buffers can filter both surface and subsurface runoff before it reaches the waterway. The rooting systems of riparian buffers can also serve to stabilize banks and soils especially along ditches that pass through mucky or easily erodible soil.

Field Borders
Field borders are 20-ft wide filter strips or bands of perennial vegetation planted at the edge of fields that can be used as turning areas for machinery. They also provide wildlife cover, protect water quality, and reduce sheet, rill, and gully erosion. Borders should be repaired and reseeded after storms and should be mown and harvested in late summer to early fall to encourage growth for the next spring.

Shelterbelts/Windbreaks
Shelterbelts are rows of trees, shrubs, or other vegetation used to reduce wind erosion and protect crops while also providing protection for wildlife, livestock, houses, and other buildings. Similar to shelterbelts, windbreaks or hedgerows are located along crop borders or within fields themselves. Air quality improvement and wildlife habitat provision are the greatest benefits of these vegetation belts.

Grassed Waterways
Grassed waterways are natural or constructed channels that are seeded with filter vegetation and shaped and graded to carry runoff at a non-erosive velocity to a stable outlet and vegetated filter. Vegetation in the waterway protects the topsoil from erosion and prevents gully formation, while providing cover for wildlife. The stable outlet is designed to slow and spread the flow of water and direct it towards the vegetated filter.

Grassed waterways are typically used where water tends to concentrate, like in draws, washouts, or other low-lying gully areas. They can also be used as outlets from other conservation practices (like terraces) or in any other situation where a stable outlet and vegetated filter can be built and maintained.

These vegetated systems may be trapezoidal or parabolic in shape, but should be broad and shallow in construction. They should be able to carry the runoff of a 10-year storm event. The stable outlet should be planted with perennial, sod-forming grasses to provide a dense area of vegetation to cause sediment and sediment-attached pollutant deposition. The vegetated area below the outlet should be constructed as a typical filter strip would be.

Proper operation and maintenance is necessary for effective grassed waterway function. Tillage and crop row direction should be perpendicular to the waterway to allow drainage and to prevent water movement along edges. Machinery crossing areas should be stabilized to prevent damage to the grassed waterway. Vegetation within the filter should be protected from direct herbicide applications. Certain species may be more tolerant of certain herbicide chemicals. It is also important to keep the strip and its outlet as wide as is possible. The waterway may need reconstruction from time to time to maintain proper shape.

Shallow Water Areas
Shallow water areas, including ponds and wetlands, within or near farmland provide cover and a water source for wildlife while also acting as a filter. Embankments and berms that pond water increase the land's water storage capacity helping to reduce volumes and flow rates of runoff. Constructed wetlands contribute to water quality improvement by: 1) reducing coliform bacteria by 90% (Reed and Brown, 1992); 2) fostering growth of microbes that recycle and retain nutrients (Wetzel, 1993); 3) providing additional adsorption sites for nutrients through the decomposition of organic matter (Kenimer et al., 1997); 4) providing anaerobic areas where denitrification processes can release nitrogen to the atmosphere; 5) degrading organic materials thereby decreasing biological oxygen demand (BOD); 6) offering sedimentation and filtration processes which remove suspended solids and adsorbed nutrients; and 7) providing flood water storage to attenuate peak flood flows. Potential sites for wetland restoration or construction will be discussed in the Aerial Tour and Windshield Survey Sections of this report.

Wellhead Protection Area
Wellhead protection areas help assure the quality of public water supplies drawn from wells. Continuous CRP enrollment is available for land within a 2000-ft radius of a public well. Vegetation planted in these areas can further help prevent water supply contamination.

Cover Crops
The use of cover crops, such as winter wheat, prevents soil from being exposed through the winter and early spring months when some of the most pronounced runoff events may occur in Indiana. Cover crops reduce surface runoff by as much as 50% due to increased infiltration (Unger et al., 1998). Reductions in both the dissolved and particulate forms of nitrogen and phosphorus have also been documented.

Other Conventional Structural Conservation Practices
A wide variety of other conventional structural conservation practices have been prescribed and are in use in various areas of the county. Although not all practices are applicable in every

situation, systems of two or more structural BMPs used in concert are often required to achieve the desired conservation benefit. A complete listing of the over 160 different conservation practices recognized by the USDA is available online at http://www.ncg.nrcs.gov/nhcp_2.html. The website offers standards and more details for each practice in a portable document format (PDF) and in MS-Word format. Structural conservation practices that are relevant for use in the Curtis Creek Watershed are listed in Appendix 2.

Conventional Managerial Conservation Practices

Managerial BMPs are those that involve behavior or decisions made with respect to normal land use operation. Commonly used practices include conservation tillage, rotational grazing, and pesticide management. Managerial conservation practices are often less expensive because they do not involve building a structure; however, successful implementation may require changing habitual behaviors and some trial-and-error experimentation. Several commonly used managerial practices are discussed below.

Conservation Tillage

Removal of land from agricultural production may not be economically feasible in some cases. Conservation tillage offers the potential for reducing erosion without removing the land from production. Conservation tillage is a crop residue management system that leaves at least one-third of the soil covered with crop residue after planting. Table 21 offers a description of the different tillage types. No-till, ridge-till, and mulch-till are all examples of conservation tillage.

Aside from saving time for the producer, a comprehensive comparison of tillage systems shows that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (CTIC, 2000). Figure 10 illustrates calculations of soil loss with respect to the "tolerable" amount of soil (T) that can be lost while still maintaining the productivity of the soil through natural formation processes. On average, all tillage methods exceed the T value for Indiana soils; however, soil loss is less using no-till and mulch tillage. Reductions in pesticide loading have also been reported (Olem and Flock, 1990). In his review of Indiana lakes, Jones (1996) documented lower lake Trophic State Index (TSI) scores in ecoregions with higher percentages of conservation tillage. A TSI is a score that condenses water quality data in a single, numerical index. Higher scores indicate evidence of eutrophication (overproductivity) or poorer water quality. No-till practices are also good for wildlife. North Carolina researchers have found that crop residues provide the food that quail chicks need to survive the first few weeks of life (Osmond and Gale, 1995). Additionally, conservation tillage reduces carbon dioxide emissions from the soil. Carbon dioxide, the most ubiquitous of the greenhouse gases, is being found at ever-increasing concentrations in the atmosphere and has been linked to global warming.

TABLE 21. Tillage type descriptions.

Type	Description	% Remaining Residue	Conservation Tillage Type?
No-till/strip-till	soil is undisturbed except for strips up to 1/3 of the row width	>30%	Yes
Ridge-till	4-6" ridges are formed on strips up to 1/3 of the row width	>30%	Yes
Mulch-till	full width of the row is tilled using only one or two tillage passes	>30%	Yes
Reduced-till	full width of the row is tilled using multiple tillage passes	16-30%	No
Conventional-till	full width of the row is tilled using multiple tillage passes	<15%	No

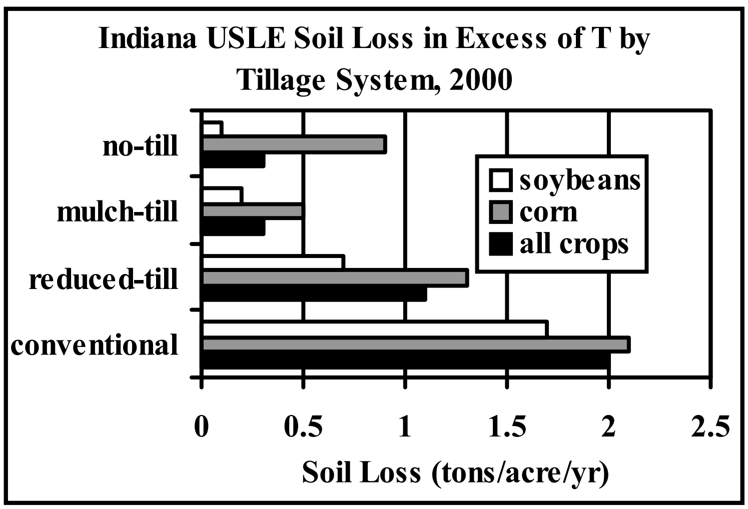


FIGURE 10. Indiana average USLE soil loss in tons/acre in excess of T by tillage system for 2000. USLE is the Universal Soil Loss Equation. Values shown are in excess of T, which is the "tolerable" amount of soil that can be lost while maintaining the productivity of the soil. Most Indiana soils have a T-value of 3-5 tons per acre per year.
Source: Clean Water Indiana Education Program, Purdue University.

Agricultural economists with the Ohio State University Extension have reported that farmers adopting conservation tillage in the Maumee and Sandusky River Watersheds saw modest decreases in farm production costs (Indiana Agrinews, 2001). During that same time period, monitoring data showed decreased loading to Lake Erie of many non-point source pollutants that are related to farming. The researchers reported individual farm savings of 2-8% in labor costs and 6-15% in machinery operation costs; however, farmers adopting no-till practices did incur a 10-18% increase in herbicide costs due to lack of tillage for mechanical weed control.

While conservation tillage has been shown to reduce total phosphorus and total nitrogen in surface runoff by as much as 70 and 75% respectively, increased dissolved phosphorus and nitrate losses have been documented (Sharpley and Smith, 1994). In the Sharpley and Smith (1994) study, nitrate concentrations in surface runoff increased from 4.5 to 29 mg/l and dissolved phosphorus concentrations in surface runoff were 300% higher. The increase in nitrate was attributed to increased soil infiltration that occurs with conservation tillage. Higher phosphorus concentrations were attributed to leaching of the nutrient from crop residue and preferential transport of smaller-sized soil particles that is associated with no-till practices. Another study by the Ohio State University Extension also documented 10-15% increases in nitrate runoff to local streams (Indiana Agrinews, 2001) and suggested that conservation tillage time savings allowed farmers to substitute winter wheat planting with corn, requiring higher amounts of nitrogen fertilizers.

Tillage Patterns in the Curtis Creek Watershed

While conservation tillage patterns were not estimated for the study watershed, they are in use throughout Jasper and Newton Counties and on many fields within the watershed. Tables 22 and 23 show conservation tillage usage patterns in the growing season of 2001 and 2002 for these counties.

TABLE 22. Percent (number) of crop fields with tillage systems in the growing season of 2001 for Jasper and Newton Counties. N/A refers to those fields where the field was not tilled. Unknown (Unk.) refers to those fields where tillage type could not be determined.

County	No-till	Ridge-till	Mulch-till	Reduced-till	Conventional-till	N/A	Unk.
Corn							
Jasper	17 (55)	0 (1)	28 (87)	41 (129)	14 (44)	0 (0)	0 (0)
Newton	29 (68)	0 (0)	26 (61)	38 (90)	7 (16)	0 (0)	0 (0)
Soybeans							
Jasper	43 (93)	0 (0)	50 (109)	6 (12)	2 (4)	0 (0)	0 (0)
Newton	54 (105)	0 (0)	39 (77)	6 (11)	2 (3)	0 (0)	0 (0)
Small Grain							
Jasper	0 (0)	0 (0)	0 (0)	0 (0)	100 (3)	0 (0)	0 (0)
Newton	0 (0)	0 (0)	0 (0)	40 (2)	40 (2)	20 (1)	0 (0)
Hay/Forage							
Jasper	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (15)	0 (0)
Newton	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (18)	0 (0)
Fallow/Other							
Jasper	11 (1)	0 (0)	0 (0)	0 (0)	22 (2)	67 (6)	0 (0)
Newton	0 (0)	0 (0)	9 (2)	0 (0)	4 (1)	87 (20)	0 (0)

Source: Purdue Cooperative Extension Service, 2002.

TABLE 23. Percent (number) of crop fields with tillage systems in the growing season of 2002 for Jasper and Newton Counties. N/A refers to those fields where the field was not tilled. Unknown (Unk.) refers to those fields where tillage type could not be determined.

County	No-till	Ridge-till	Mulch-till	Reduced-till	Conventional-till	N/A	Unk.
Corn							
Jasper	13 (36)	0 (0)	19 (54)	30 (85)	39 (111)	0 (0)	0 (0)
Newton	23 (57)	0 (0)	25 (62)	32 (78)	19 (47)	0 (0)	0 (0)
Soybeans							
Jasper	48 (118)	0 (0)	33 (82)	13 (32)	6 (15)	0 (0)	0 (0)
Newton	55 (100)	0 (0)	31 (56)	10 (18)	4 (7)	0 (0)	0 (0)
Small Grain							
Jasper	0 (0)	0 (0)	0 (0)	67 (2)	0 (0)	0 (0)	33 (1)
Newton	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (20)	0 (0)
Hay/Forage							
Jasper	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (12)	0 (0)
Newton	0 (0)	0 (0)	0 (0)	0 (0)	100 (1)	0 (0)	0 (0)
Fallow/Other							
Jasper	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	50 (2)	50 (2)
Newton	0 (0)	0 (0)	0 (0)	0 (0)	4 (1)	96 (24)	0 (0)

Source: Purdue Cooperative Extension Service, 2002.

Producers in both Jasper and Newton Counties grew most of their corn and soybean crops using a conservation tillage method. In both counties, producers utilized reduced-till methods on the majority of the land used for corn production, while soybean producers utilized no-till or mulch-till methods (Purdue Cooperative Extension Service, 2002). While no-till was the most commonly used conservation tillage technique, mulch till and reduced till were also used with some frequency. In general small grains were grown on soils that were conventionally tilled or reduced-tilled. Of the 92 counties in Indiana, Jasper County ranked 51st and 65th for percent of corn and soybeans, respectively, planted using a no-till system in 2001 and 49th and 60th for 2002 (Evans et al., 2000). Newton County ranked 31st and 51st, respectively in 2001 and 30th and 52nd in 2002. These numbers suggest that more producers could be utilizing conservation tillage methods in the study counties. If producers did so, their efforts would likely improve water quality in the watershed.

In 2000, conservation tillage was used on 45% of Indiana's cropland. Even though Indiana is a no-till leader among cornbelt states, data suggest that few fields were no-tilled over the long term. Given that most research suggests that no-till benefits to soil begin to appear no earlier than the 3rd consecutive year of no-till, many farmers are abandoning no-till at about the time one would expect its benefits (Evans et al., 2000). Data from the Purdue Agronomy Research Center suggest that over the past 25 years, no-till used in a corn-soybean rotation economically outperformed conventional, mulch, and strip tillage systems (West et al., 1999). Producers should be encouraged to give no-till practices the continuous time necessary to reap yield, economic, and environmental benefits. Mark Evans of the Purdue Cooperative Extension Agency believes that use of conventional tillage methods will be greatly increased in 2002 due to extremely wet fall and spring conditions throughout northern Indiana. Heavy rains enhance rill and gully erosion problems, thereby requiring tillage prior to planting. Tillage transect data listed in Tables 22 and 23 indicate increases in conventional tillage for soybeans and corn in both Newton and Jasper Counties.

Producers that switch to a conservation tillage pattern should keep in mind that the normal planting process and management regime may need to be modified or "fine-tuned" for success. Tillage will no longer destroy weeds before planting, and new weed species will invade given the different soil conditions. Treating these new invaders may require different herbicides. Certain crop varieties may not tolerate the change in herbicide regime, so a different crop variety may be required. Yield reduction which at first may be associated with tillage change may be due in fact to a different level of tolerance to a new herbicide (Canada-Ontario Green Plan, 1997).

Nutrient Management Research

Nutrient management has been the focus of agricultural research in many parts of the country. Studies have shown that every year about 15% of the applied nitrogen, 68% of the residual nitrogen in the non-root zone layer of the soil, and 20% of the residual nitrogen in the root zone layer are leached to the groundwater (Yadav, 1997). To address this concern, the Penn State Cooperative Extension Service designed a nutrient management plan based on: 1) crop yield goals; 2) soil type; 3) methods of manure and commercial fertilizer application; 4) nitrogen concentrations in soils; 5) nitrogen concentrations in manure to be used for fertilizer; and 6) crop rotations (Hall and Risser, 1993). With this plan in place: 1) fertilizer application as manure and commercial fertilizer decreased 33% from 22,700 lbs/year to 15,175 lbs/year; 2) nitrogen loads in groundwater decreased 30% from 292 lbs of nitrogen per 1,000,000 gal of groundwater to 203 lbs per 1,000,000 gal; and 3) the load of nitrogen discharged in groundwater was reduced by 11,000 lbs for the site over a three-year period (70 lbs/ac/yr).

Nutrient Management in the Curtis Creek Watershed

Producers in the watershed typically apply phosphorus and potash during the fall and anhydrous ammonia at spring planting (Dan Ritter of the Newton County Purdue Cooperative Extension Agency (PCEA) and Mike Manning of the Jasper County PCEA, personal communication). Depending upon the producer, additional fertilizer applications can occur into early June (Mike Manning, personal communication). Many producers also grow winter wheat after the corn or soybeans have been harvested so that their manure can be utilized year-around. Dan Ritter estimates that there are 15,000 head of dairy cattle, 1,200 hogs, and 250,000 poultry animals within Newton County. Manure application is commonly utilized as fertilizer in areas where animal operations are common (the northern portion of the watershed).

Management of nutrients in fertilizer can greatly benefit water quality. The first step in effective nutrient management is regular soil testing. Historically, producers conducted soil tests only when a problem is noticed. More recently, soil testing has occurred every 2-3 years (Dan Ritter, personal communication). In most cases, soil testing frequency is dependent upon the individual producer with some producers testing much more frequently than others (Mike Manning, personal communication). Many producers, especially those applying manure, have adopted annual soil testing. Dan Ritter believes that those utilizing manure as a fertilizer follow Indiana Department of Environmental Management (IDEM) guidelines for nitrogen application rates.

Fertilizer should be applied based on realistic yield goals; generally realistic yield goals are utilized for fertilization in Jasper County (Mike Manning, personal communication). However, Newton County producers' application rates are based more on optimal yields rather than realistic yield goals or a yield history of 140-150 bushels/acre. Producers should also make allowances in nitrogen application for nitrogen contributions of any previous legume crops in the rotation or any legume cover crops. Dan Ritter stated that most farmers in Newton County use a soybean-corn rotation and do typically account for legume nitrogen-addition in their fertilizer regimes. Fertilizer adjustments may also be necessary when transitioning from conventional to conservation tillage.

In special areas of environmental concern, such as fields that border streams and other waterbodies, fertilizer setbacks should be utilized. Setbacks are strips or borders where fertilizer is either not applied or applied in smaller quantities. Fertilizers should not be applied directly next to streams and certainly not in them. According to the Newton County Purdue Cooperative Extension Agency, fertilizer setbacks are accomplished with filter strips, and most farmers are conscientious near tile drains and open ditch areas. Producers utilizing highly erodible soils in areas of environmental concern tend to be more conscientious with respect to fertilizer application. Many producers in these areas utilize CRP near open drainage tiles and ditches.

Though not a nutrient *E. coli* bacteria contamination of waterways is an indirect effect of applying animal waste as fertilizer. *E. coli* and other bacteria from the intestinal tracts of warm blooded animals can cause gastroenteritis in humans and pets. Symptoms of gastroenteritis include: nausea, vomiting, stomachache, diarrhea, headache, and fever. Due to high *E. coli* counts, about 81% of the assessed waters in Indiana did not support "full body contact recreation" in 1994-1995 (IDEM, 1995). Producers utilizing manure application practices can take precautionary steps to ensure that bacteria and manure do not contaminate streams and ditches. To prevent manure from entering tiles, ditches, and streams, producers can: 1) apply manure at optimal times for plant uptake; 2) apply when potential for plant uptake is high and runoff is low; 3) inject or incorporate manure to reduce runoff potential; 4) use filter strips; and 5) use setbacks from surface inlets to tile lines.

Weed and Pest Management

Groundwater data assembled by the U.S. Geological Survey (USGS) and the Environmental Protection Agency (EPA) found 18 pesticides and five pesticide breakdown products in 9% of the samples taken in Indiana (Goetz, 2000). Modeling by Purdue University professor Bernie Engel, showed that 75% of detectable pesticides in groundwater came from 25% of farmland. Using his data, Dr. Engel created a pesticide leaching risk map (Figure 11) and helped the State write the Indiana State Pesticide Management Plan. This plan is available on-line at http://www.isco.purdue.edu/psmp/oiscmain.html. Given the extremely high risk of pesticide leaching in the northern portion of the Curtis Creek Watershed, weed and pest management is of particular importance. Moderately high risk of pesticide leaching also makes weed and pest management important in the lower portion of the watershed.

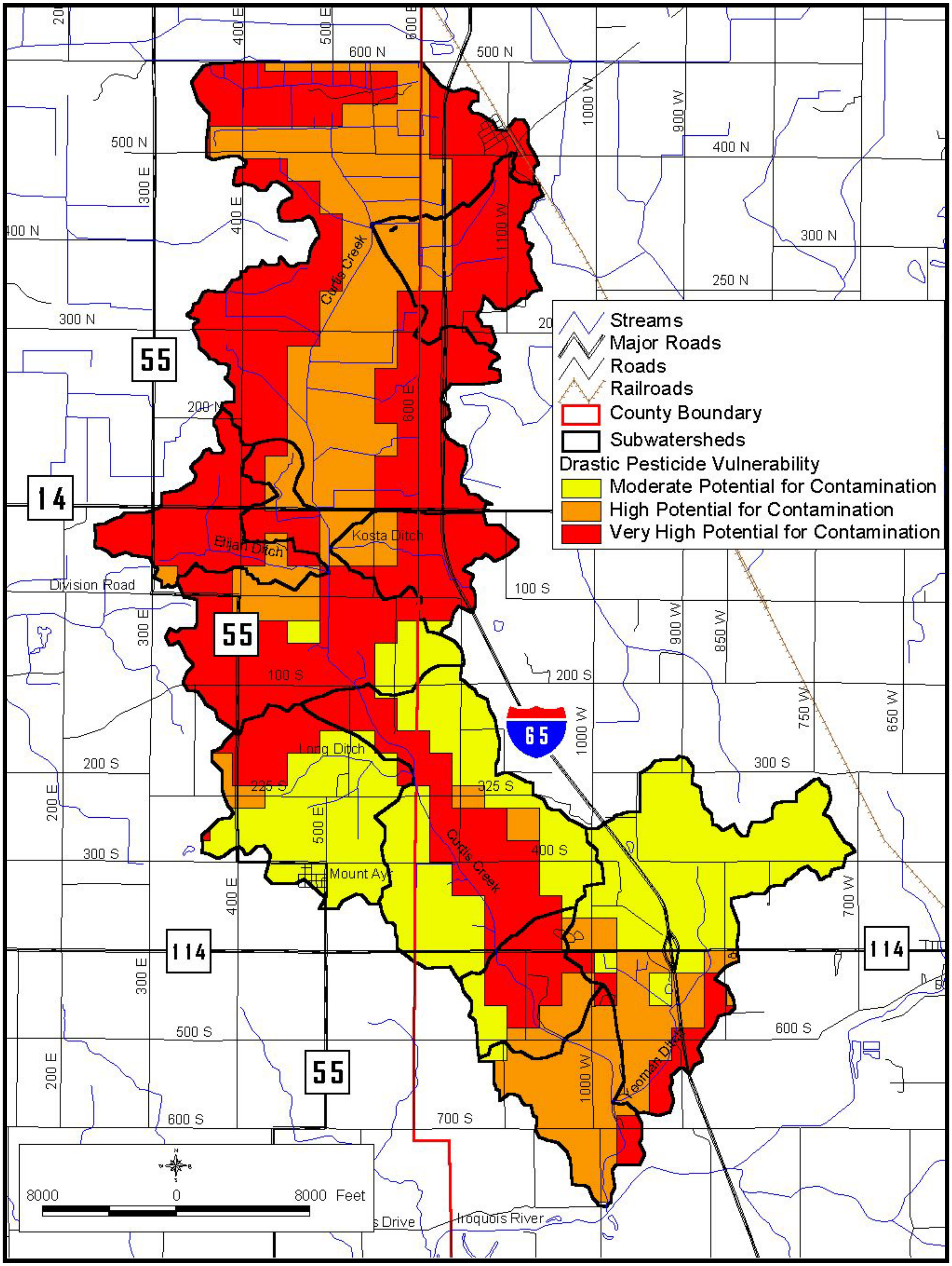


FIGURE 11. Pesticide leaching risk map.

Weed and pest management results in fewer herbicide and pesticide applications at reduced rates and thereby helps to protect the environment by reducing polluted runoff and reduces producers' operating costs. Proper management of these chemicals entails: 1) being familiar with the threshold at which weed and pest populations begin to cause economic damage; 2) using local weather forecasting to time field scouting to determine if pest problems are great enough to warrant the use of a control measure; 3) planting cover crops to suppress weed growth; 4) planting seed that has been bred for pest resistance during optimal conditions; 5) using insect traps near target crops to track infestations; 6) promoting and attracting natural enemies that help control pests; and 7) applying the most effective and appropriate pesticide or herbicide during optimal weather conditions.

Properly functioning tile lines have been shown to reduce pesticide contamination of water by: 1) decreasing runoff so less pesticide is carried in water and 2) soil particles adsorbing many of the chemicals as water runs through the soil on its way to tiles (Goetz, 2000). In fact, compared to pesticide runoff in surface water, relatively little soaks down through the soil into the groundwater (Kladivko, 1999). Although it may vary with soil type, the amount of pesticide that enters tile lines is generally less than half a percent of the amount applied. Meanwhile, surface runoff from poorly drained fields during the first or second storm after application can contain 1-2% of the pesticide applied. Based on her research Purdue agronomy professor Eileen Kladivko recommends that farmers properly tile poorly drained fields if they are to be used for production to avoid possible surface water contamination with pesticides (Goetz, 2000).

Weed and Pest Management in the Curtis Creek Watershed

In both Newton and Jasper Counties, herbicides are applied based on season and weather patterns, while pesticide is applied based on need. In Jasper County, herbicide application is typically applied from April to June (Mike Manning, personal communication). Insect scouting is a cooperative effort between farmers and pesticide applicators. In Newton County, pesticide dealers or agronomists conduct most of the insect scouting. According to the Newton County Purdue Cooperative Extension Agency western corn rootworm, black cutworm, European corn borer, and Japanese beetles are the most common pests. Interestingly, an additional advantage of crop rotation (which is avidly used within the study area) helps to break the annual life cycles of most typical crop insects (Jeff Burbrink of the Elkhart County Purdue Cooperative Extension Agency, personal communication).

Resource Management Planning

Resource management planning is an individually based natural resource problem solving and management process advocated by the NRCS (NRCS, 2001). It addresses economic, social, and ecological concerns to meet both public and private needs while emphasizing desired future conditions. NRCS personnel work directly with landowners to understand his or her objectives to ensure that all parties understand relevant resource problems and opportunities and the effects of decisions. The process has three phases and nine steps:

Phase I – Collect and Analyze

1. Identify Problems and Opportunities
2. Determine Objectives
3. Inventory Resources
4. Analyze Resource Data

Phase II – Decision Support
5. Formulate Alternatives
6. Evaluate Alternatives
7. Make Decisions

Phase III – Application and Evaluation
8. Implement the Plan
9. Evaluate the Plan

Though not widely used, Resource Management Plans have met with success in most areas. According to Doug Nusbaum, an agriculture conservation specialist with the Indiana Department of Natural Resources (personal communication), most if not all fields (including highly erodible ones) can be responsibly managed and used for production with the development of a Resource Management Plan. Planning involves inventorying the resources, communicating with the landowner about where improvements may be made, and implementing the plan.

Other Conventional Managerial Conservation Practices

The USDA has published specifications for management-oriented practices in addition to the more common ones described above. Again not all practices are applicable in every situation, but managerial BMPs used in concert with structural BMPs are often required to meet conservation goals. A list of the various different conservation practices recognized by the USDA is available online at http://www.ncg.nrcs.gov/nhcp_2.html. Managerial conservation practices that are relevant for use in the Curtis Creek Watershed are listed in Appendix 2.

Innovative/Newly Developed Conservation Practices

Researchers interested in agriculture and conservation are testing new ideas for production management every day in the United States and Canada. A comprehensive literature search was conducted as part of the current study. BMPs that may present promise of water quality benefit in certain situations are presented below. It should be noted that some of the practices have been developed fairly recently, and successful results cannot yet be guaranteed.

Riparian Management System Model

The Agroecology Issue Team of the Leopold Center for Sustainable Agriculture and the Iowa State University Agroforestry Research Team banded together in the early 1990s to promote restoration of the Bear Creek Watershed in central Iowa via development of a riparian management system model. Results of their study provide valuable lessons relative to management decisions and practices in the Curtis Creek Watershed. The purpose of the study was to design a management system composed of several parts so that each part could be modified individually to meet site conditions and landowner objectives. Specific goals of the management system include: interception of eroding soil and agricultural chemicals, slowing of flood waters, stabilization of streambanks, and provision of wildlife habitat and an alternative, marketable product (Isenhart et al., 1997). The system model consists of a multispecies riparian buffer, streambank stabilization, a constructed wetland, and a rotational grazing strategy (Figure 12).

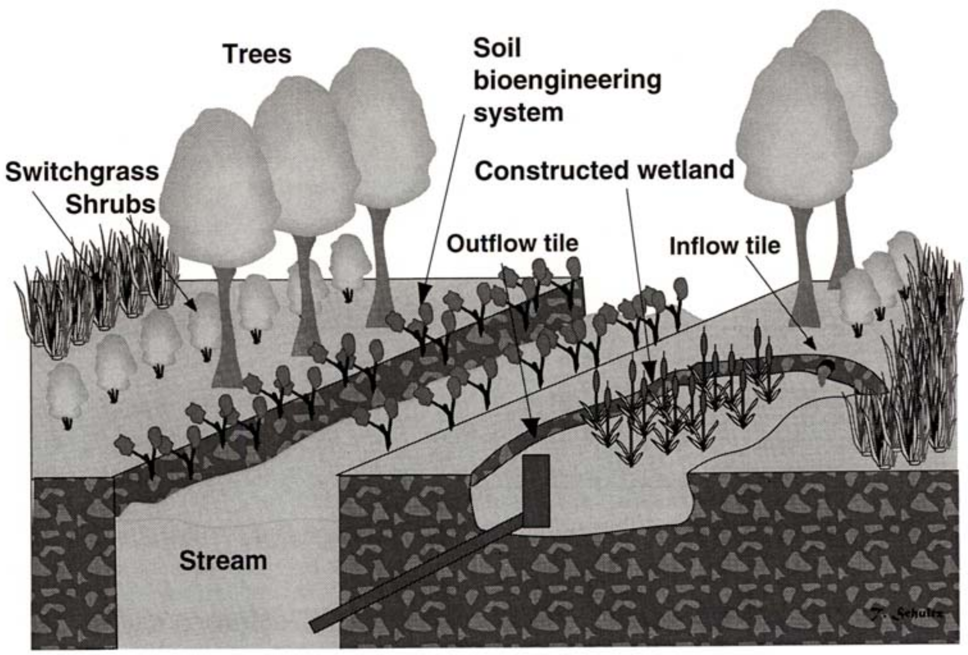


FIGURE 12. The riparian management system model (Isenhart et al., 1997). Used with permission from the American Fisheries Society.

The riparian buffer strip component consists of three zones (Figure 13): 1) A 33-foot-wide strip of trees bordering the stream. Fast-growing, native species like green ash, willow, poplar, and silver maple are recommended. Slower-growing trees like oaks and walnuts may be planted in the outer edge if desired. 2) A 12-foot-wide strip of shrubs. Shrubs, like trees, have permanent rooting structures and offer habitat diversity. Recommended species include ninebark, redosier and gray dogwood, chokeberry, witch hazel, nannyberry, and elderberry. 3) A 21-foot-wide strip of warm-season grasses. Species mixes were discussed in the filter strip section. Altogether the strip is 66 feet wide, but each component may be altered to address landscape requirements, desired physical and/or biological functions, landowner objectives, and cost-share program standards. Appendix 3 includes before and after pictures of a riparian management system installation site in the Bear Creek Watershed.

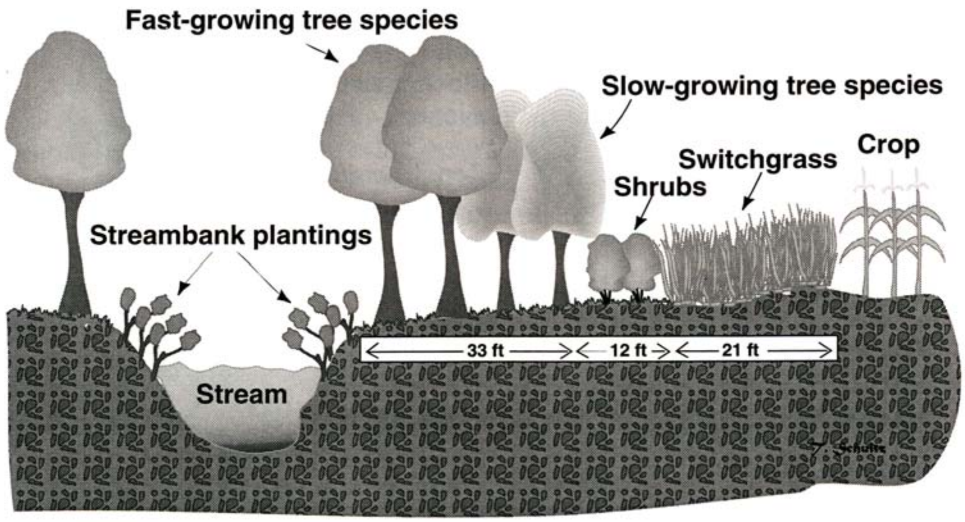


FIGURE 13. The multispecies riparian buffer strip component of the management system model. Used with permission from the American Fisheries Society.

Streambank stabilization using bioengineering techniques is the second component of the comprehensive riparian management system model. Feasible techniques include installation of native, live plant material in combination with revetments of rock or wood and biodegradable erosion control fabric. According to Klingeman and Bradley (1976) bank vegetation provides numerous stabilization benefits such as: 1) plant roots hold soils together and in place; 2) above-ground vegetation increases surface flow resistance, decreasing flow velocities and routing energy dissipation toward plant material and away from soils; 3) vegetation buffers the channel from abrasion by materials transported from upstream; and 4) vegetation induces sediment deposition, helping to keep soil on the land and to rebuild streambanks.

The final two components of the model include a constructed wetland designed to fit into the 66-foot buffer strip and a rotational grazing system to control livestock stream access. Constructed wetlands have a known track record for nitrate removal (via the process of denitrification) from surface water. In the Iowa study, water from a 12-acre field discharged into a 2,900 ft^2 (<0.10 acre) wetland. A gated tile at the outlet of the wetland provides control of water levels (Figure 13). Vegetation was planted in the wetland to jump-start nutrient uptake. (See Appendix 3 for photo and Table 24 for a list of plants recommended for wetland planting.) Other studies suggest that a wetland area to cultivated crop area ratio of 1:100 will provide the water retention time during normal runoff events necessary to remove a significant amount of nitrate.

TABLE 24. Plant species suitable for filtration and nutrient uptake in restored or constructed wetlands.

Grasses	Forbs
Redtop	Sweet flag
Creeping bent grass	Common water plantain
Spike rush	Cardinal flower
Common rush	Great blue lobelia
Rice cut grass	Monkey flower
Soft-stem bulrush	Arrow arum
Bur reed	Smartweed
Temporary Grasses	Pickerel weed
Seed oats	Broad-leaf arrowhead
Annual rye	

*Note: Seed the permanent grasses at 3 lbs/acre, the temporary grasses at 42 lbs/acre, and the forbs at 2.75 lbs/acre.

Monitoring is an important part of any study, and as such, the Bear Creek project sites were monitored for success (Isenhart, et al., 1997). The monitoring studies indicated that the 21-foot-wide switchgrass component of the model reduced sediment load to the stream by 75%. Nitrate-nitrogen concentrations moving in groundwater below the buffer were markedly lower than those moving below the adjacent, cropped field. Nitrate levels below the buffer never exceeded 2 mg/l while levels below adjacent cropped fields consistently exceeded 12 mg/l (Schultz et al., 1995). In contrast, groundwater nitrate concentrations in a field cultivated to the stream's edge showed no reduction nearer the stream. Wildlife use of the restored area was also markedly improved. While only four bird species per day were observed in channelized reaches, 18 species per day were recorded in 4-year-old buffer sections. Additionally, constructed wetland outflow concentrations of nitrate-nitrogen were significantly lower than inflow concentrations during most sampling periods.

The Iowa management system model provides valuable lessons for management within the Curtis Creek Watershed. The approach is flexible for site-specific conditions and respectful of private landowners' desires and objectives. Within the Bear Creek Watershed, two relatively small sites were initially built and then used to garner the interest and support of other landowners. Similar management system models hold great promise for application within the study watershed and include the following major advantages: 1) interception of eroding soil; 2) trapping and transformation of non-point source pollution; 3) stabilization of stream banks; 4) provision of wildlife habitat; 5) production of biomass for on-farm use; 6) production of high-quality hardwood; and 7) enhancement of agro-ecosystem aesthetics (Schultz et al., 1995).

Natural Nitrification Stimulation

Growers Nutritional Solutions of Milan, Ohio has researched and recommends a nutrient management plan that stimulates natural nitrification processes in the soil. The program has been recognized by the Environmental Protection Agency as having environmental benefits because less commercial nitrogen needs to be applied (Halbeisen, 2001). The plan has applications and can be used in both agricultural and residential lawn care situations.

The natural nitrification program involves: 1) supplying adequate amounts of calcium to the soil profile and 2) foliar fertilization using high-grade, balanced fertilizer solutions. Research shows that calcium: 1) stimulates nitrogen-fixing soil bacteria like *Azotobacter* which can fix 15-40 lbs of nitrogen/acre/year (Smith et al., 1953); 2) prevents increased solubility of iron and aluminum which negatively affects nitrogen fixation; 3) increases soil porosity and oxygen exchange which are important for the conversion of nitrogen to a form that can be used by plants; 4) stimulates earthworm populations, which shred organic matter for bacterial consumption and help to decrease soil compaction. The second part of the program requires applying a small amount of balanced fertilizer on the seed at planting. The crops are then fed through the foliage at certain stages of development. Research shows that foliar-applied fertilizer is used more efficiently than soil-applied nutrition (Joint Committee on Atomic Energy, 1954). Advantages of using the two part program include: 1) lowered use of applied nitrogen; 2) sound economic productivity; 3) higher grain weights; 4) better produce flavor and shelf life; 5) fewer livestock veterinary visits (Halbeisen, 2001).

Integration of Nitrogen and Phosphorus Management

Recent research has suggested the need for integrated nitrogen and phosphorus management to account for spatial variation in nutrient loss risk (Heathwaite et al., 2000). While nitrate-nitrogen loss from landscapes is a threat to groundwater supplies, phosphorus loss threatens rivers, lakes, and oceans with eutrophication (overproduction). Nitrogen as nitrate is highly mobile in leaching water and is primarily lost through subsurface runoff. (Figure 14 shows areas of the Curtis Creek Watershed that are vulnerable to nitrate loss via leaching according to modeling work by Purdue University engineering professor Bernie Engel.) On the other hand, phosphorus is predominantly lost via surface runoff. Because the two nutrients are transported by such different mechanisms, different management tools should be employed depending on which nutrient is of the highest risk of being lost. For example, it does not make sense to prioritize management of phosphorus in an area of the watershed that rarely contributes surface runoff and that does not receive high amounts of the nutrient. Different sections of even a single tract of land may need to be managed differently based on risk of nutrient loss.

In many cases, "across-the board" management of only one nutrient may in fact heighten the risk of pollution by the other. For example, when manure fertilization regimes are based on soil nitrogen content alone to manage nitrate leaching, phosphorus is often over-applied. The amount of phosphorus applied relative to nitrogen (N:P = 2:1 to 6:1) is often greater than that which can be taken up by crops (N:P = 7:1 to 11:1) (Eck and Stewart, 1995). In contrast, use of artificial drainage to reduce phosphorus loss by reducing surface runoff may enhance nitrate leaching through the ground (Turtola and Paajanen, 1995).

Individual tracts of land can be assessed for nutrient loss risk by applying nitrogen and phosphorus indexing systems to assign risk ratings (Heathwaite et al., 2000). The nitrogen index is based on soil texture and permeability, fertilization rate and method, and manure application rate and method. The phosphorus index is based on erosion potential, amount of runoff that leaves the site, distance from the site to the nearest waterway, soil test phosphorus, fertilization rate and method, and manure application rate and method. By calculating the index value for each nutrient, loss vulnerability for the site can be determined and management tailored accordingly.

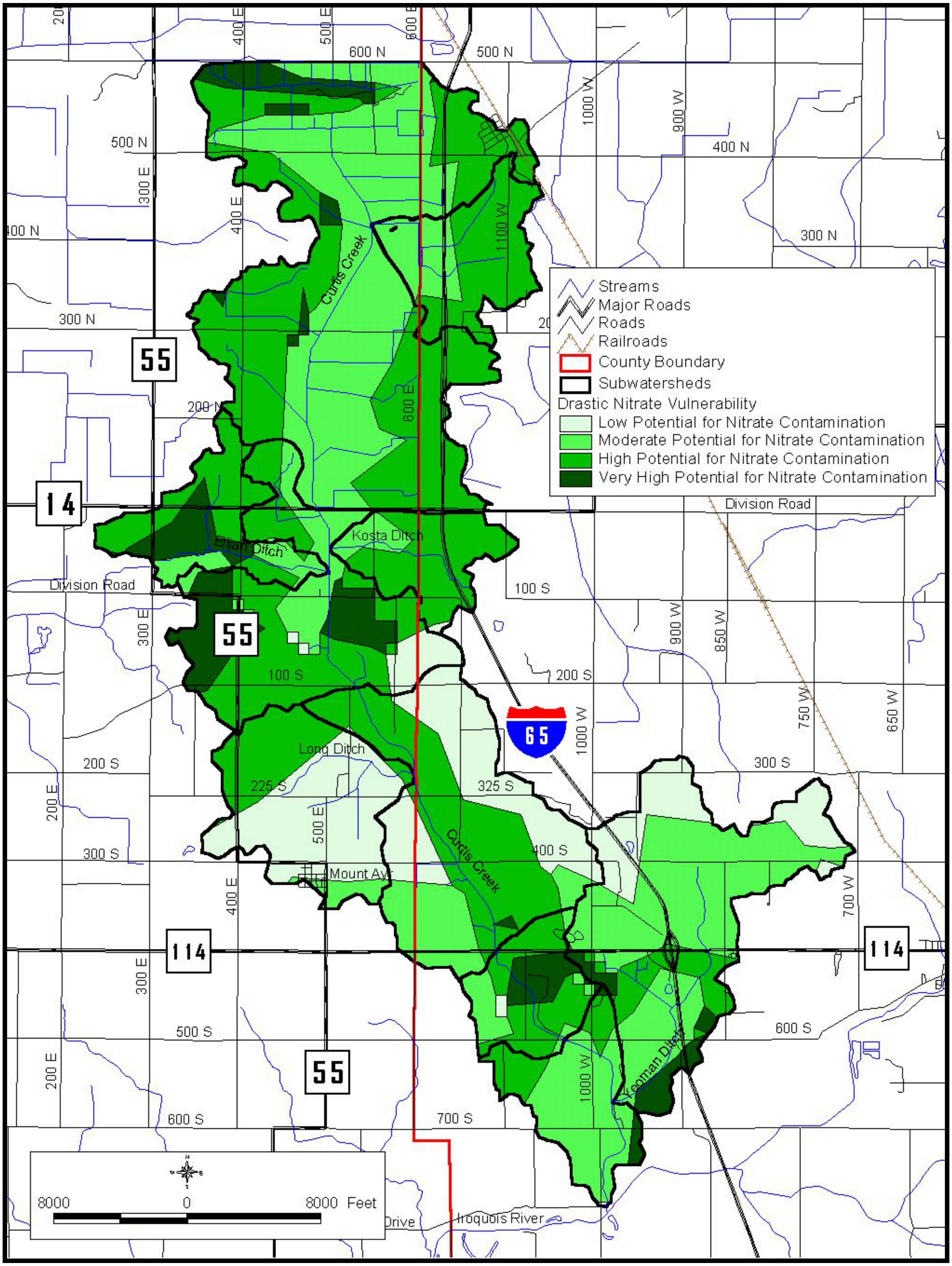


FIGURE 14. Nitrate leaching risk map.

In areas that are phosphorus-loss prone, fertilizer and manure applications should be appropriately modified and features that slow surface runoff should be installed (i.e., constructed wetlands and filter strips). In areas where nitrogen loss is a hazard, nitrogen sources and sinks like fertilizer, crop type, and crop rotation should be carefully monitored. Different management priorities may be suited to different areas of a watershed or tract of land.

Water Treatment Residual Application to Reduce Nutrient Loss
Recent research shows that residual chemicals produced during the drinking water purification process may retard nutrient loss from animal wastes applied as fertilizers (Gallimore et al., 1999). Water treatment residuals (WTR) are composed of sediment, aluminum oxide, activated carbon, and polymer. Runoff from plots fertilized with poultry litter including WTRs contained 50% less dissolved phosphorus and 66% less ammonium when compared to runoff from control plots which received poultry litter alone. Land application of the WTR did not increase total dissolved solids or aluminum in surface runoff. The study did note, however, that WTR may damage pasture vegetation and is discouraged in these locations (Gallimore et al., 1999).

Systems of BMPs
Although individual BMPs are commonly and have traditionally been used, recent work shows that BMPs used in concert working as a system will often be more effective at pollution control than individual practices (Osmond et al., 1995). Systems of BMPs function to minimize the pollutant at several points including the source, the transport process, and the water body. For example, the goal of an Iowa Rural Clean Water Program (RCWP) project, was to protect Prairie Rose Lake which was receiving sediment from the surrounding watershed. Two BMPs, critical area planting and conservation tillage, were used to diminish soil loss from agricultural land, while five BMPs including terraces, underground outlets, diversions, grassed waterways, and detention basins, were constructed to slow sediment transport to the lake (Osmond et al., 1995).

BMP Summary
Agricultural BMPs are currently used in the Curtis Creek Watershed. Although some cropland within the watershed is set aside as filter strips and grassed waterways, landowners should be encouraged to install structural BMPs and/or participate in managerial BMPs, particularly on tracts where manure is spread. Conservation tillage is readily used throughout the study watershed, but farmers should be encouraged to stay with the minimum till practices longer than 2-3 years. The best way to protect against soil loss is to keep the soil covered, minimizing disturbance. As a result of conservation tillage used in combination with other BMPs, 75% of Indiana's cropland is losing soil at or below the tolerable level of T for the 2000 growing season (Evans et al., 2000). In fact, scientific evidence indicates that about 80% of environmental issues that result from cropland can be corrected by integrating BMPs into farm management (CTIC, 1999). Comprehensive land management through development of individual Resource Management Plans is highly recommended.

Groundwater Chemistry Studies
A surface waterbody's groundwater watershed is that area below the landscape's surface that drains to the surface waterbody. Typically, a waterbody's groundwater watershed and its surface water watershed boundaries do not correspond exactly. Due to the complicated modeling involved with groundwater watershed boundary determinations, determining the boundary of the

Curtis Creek groundwater watershed was not included as a portion of this study. Nonetheless, the chemical constituents present in the groundwater aquifer can eventually reach surface waterbodies. Based on this principle, samples collected throughout Newton County through the Cooperative Private Well Testing Program directed by Heidelberg College are included in this discussion. (Please note that it is likely that not all of the samples were collected from within the Curtis Creek groundwater watershed.)

Cooperative Private Well Testing Program Study

The Heidelberg College water quality testing laboratory located in Tiffin, Ohio coordinates the nationwide Cooperative Private Well Testing Program (CPWTP). Through this program individuals can have drinking water well water samples analyzed for a wide variety of constituents including: nitrates, pesticides, metals, and volatile organic compounds (Heidelberg College, 2002). Several landowners in Newton County have taken advantage of this program. Specific tests completed on the Newton County samples included nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, chlorine, sulfate, conductivity, soluble reactive phosphorus (SRP), and silicon dioxide. Additionally, the laboratory conducted three organic compound screens. The three screens are the Pesticide Immunoassay Screen, which is a highly sensitive, low cost technique for identifying the presence of various groups of pesticides in a water sample; the Lasso/Dual/Acetochlor screen (ALASCR), which assesses concentrations of alachlor-containing pesticides, such as Lasso, Dual, or Harness; and the triazine screen (TRISCR) which indicates the presence of common triazine herbicides including AAtrex, Blades, and Princep.

Neither the state of Indiana nor the EPA have established private drinking water well standards. However, the EPA has established public drinking water standards. National Primary Drinking Water Regulations (NPDWR), or primary standards are legally enforceable standards, that apply to public drinking water supplies. Primary standards limit the levels of contaminants in public drinking water systems, thereby protecting public health (USEPA, 2002). Table 25 contains the national maximum contamination level (MCL) drinking water standards for parameters analyzed in the Newton County samples.

TABLE 25. National maximum contamination level (MCL) drinking water standards for public drinking water systems.

Parameter	Recommended Standard
Nitrate-Nitrogen (NO_3^--N as N) + Nitrite-Nitrogen (NO_2^--N as N)	1 mg/l
Nitrate-Nitrogen (NO_3^--N as N)	10 mg/l
Ammonia-Nitrogen (NH_3-N as N)	35 mg/l*
Chloride (Cl as Cl_2)	4 mg/l
Sulfate (SO_4^{2-})	400 mg/l
Conductivity	1200 μmhos/cm
Silica	--
Phosphorus	--
ALASCR	
Alachlor	0.002 mg/l
Acetochlor	--
Metolachlor	--
TRISCR	
Atrazine	0.003 mg/l
Cyanazine	--
Simazine	0.004 mg/l

Sources: National Academy of Sciences, 1972; USEPA, 1989; OAC, 1996.
*Values this high rarely occur in groundwater. Heidelberg College suggests having groundwater samples tested for bacteria if the ammonia-nitrogen concentration exceeds 0.5 mg/l.

Table 26 presents the data collected by the CPWTP in Newton County during the spring and summer of 2002. Nitrate concentrations in the samples were below the national standard (10 mg/l) in all but one of the collected samples (30.42 mg/l). Figure 15 shows the relative concentrations of nitrate-nitrogen in the samples. Samples containing high nitrate-nitrogen concentrations generally occur in the central and northern potions of Newton County. Although there is moderate to high nitrate-nitrogen leaching potential, nitrate-nitrogen does not appear to be reaching groundwater wells throughout most of the county. Chloride concentrations exceeded the national standard in 3.5% of the samples. Chloride concentrations ranged from 1-535 mg/l (median concentration 8.3 mg/l). Additional organic compound screening (ALASCR and TRISCR) was conducted on all of the fifty-seven samples and indicated the presence of pesticides or herbicides in the all of the drinking water well samples. Figures 16 and 17 display relative distributions for both the alachlor screen (ALASCR or Lasso/Dual) and the triazine screen (TRISCR), respectively. The screens indicate that an average concentration of 0.33 mg/l of organic, alachlor-containing compounds and 0.03 mg/l of organic, triazine-containing compounds were present in the well samples. ALASCR and TRISCR concentrations ranged from 0.03-7.38 mg/l and 0.01-0.08 mg/l, respectively. There is moderate to high pesticide leaching risk throughout the northern part of Newton County and low to moderate pesticide leaching risk throughout the southern portion of the county. Based on the CPWTP sampling results, pesticides do not appear to be reaching groundwater in most of the county; nonetheless, because pesticides are not normally present in private well samples collected in most areas, concentrations measured throughout Newton County are of concern (Water Quality Laboratory, 1996). (These and other parameters will be discussed in more detail in the Water Chemistry Methods Section.)

TABLE 26. Results of the Cooperative Private Well Testing Program conducted at fifty-seven locations throughout Newton County in 2002.

NO_2^--N	NO_3^--N	NH_3-N	Cl^-	Sulfate	Cond	SRP	SiO_2	TRISCR	ALASCR
0.00	0.00	0.044	17.0	74.0	567	0.025	12.63	0.04	1.12
0.00	0.00	2.773	7.3	0.0	669	0.136	14.66	0.04	0.05
0.00	0.00	0.020	8.3	39.4	262	0.016	7.95	0.04	0.06
0.00	0.00	0.310	36.9	10.2	440	0.038	5.93	0.03	0.15
0.00	0.00	1.513	3.1	22.7	591	0.124	14.05	0.04	0.05
0.00	0.00	0.600	4.1	22.3	581	0.058	17.70	0.04	0.06
0.00	0.00	0.037	1.0	0.2	472	0.055	14.49	0.06	0.08
0.00	0.00	1.842	3.0	0.0	479	0.151	13.58	0.03	0.06
0.00	0.00	0.328	3.3	0.2	491	0.028	11.31	0.02	0.03
0.00	0.00	0.035	8.1	33.1	403	0.047	10.58	0.03	0.09
0.00	0.00	0.027	27.3	56.8	534	0.047	8.06	0.02	0.09
0.00	0.00	0.631	1.0	13.4	545	0.184	13.03	0.02	0.04
0.00	0.00	0.334	9.4	0.2	645	0.241	14.20	0.04	0.04
0.00	0.00	0.446	1.8	0.0	625	0.104	11.59	0.03	0.07
0.00	0.00	0.150	330.1	68.0	1675	0.056	15.35	0.03	1.40
0.00	0.00	0.080	2.1	18.1	287	0.097	17.49	0.04	7.38
0.00	0.00	0.061	18.6	106.2	674	0.003	12.55	0.02	0.06
0.00	0.00	0.266	1.9	59.0	617	0.009	7.47	0.03	0.03
0.00	0.00	0.385	4.7	136.4	711	0.005	7.54	0.03	0.06
0.00	0.00	0.867	19.4	49.6	466	0.015	12.16	0.03	0.16
0.00	0.00	0.787	3.8	0.1	507	0.067	14.20	0.02	0.04
0.00	0.00	0.462	6.9	33.7	450	0.032	12.99	0.02	0.03
0.00	0.00	0.299	4.2	0.1	514	0.003	7.32	0.02	0.03
0.00	0.00	0.061	18.5	6.3	728	0.002	7.22	0.02	0.03
0.00	0.00	0.361	5.5	215.5	991	0.003	7.94	0.02	0.04
0.02	0.00	0.705	1.2	1.7	531	0.035	13.57	0.04	0.07
0.03	0.00	0.039	16.8	0.2	505	0.027	10.48	0.02	0.04
0.03	0.00	0.023	535.0	106.8	612	0.004	12.25	0.04	0.21
0.03	0.00	0.380	17.7	71.3	6.6	0.001	8.24	0.03	0.05
0.03	0.00	0.599	3.0	0.8	458	0.012	12.44	0.03	0.04
0.03	0.00	0.273	19.1	0.5	530	0.002	9.49	0.04	0.06
0.04	0.00	0.663	19.1	225.2	1030	0.002	8.21	0.03	0.05
0.04	0.00	0.051	8.2	59.9	364	0.018	9.20	0.02	1.84
0.04	0.00	0.682	39.4	13.9	771	0.002	6.82	0.02	0.03
0.04	0.00	0.578	58.6	0.1	672	0.039	11.72	0.04	0.08
0.05	0.00	0.511	51.1	10.2	899	0.003	7.12	0.02	0.05
0.05	0.00	0.371	18.9	0.0	557	0.014	10.87	0.04	0.05
0.05	0.00	0.016	23.4	0.1	505	0.013	10.90	0.02	0.05
0.05	0.00	2.044	16.0	75.4	787	0.002	7.30	0.02	0.04
0.06	0.00	0.630	55.5	2.1	716	0.010	11.20	0.02	0.06
0.06	0.00	0.456	19.5	13.3	535	0.011	10.20	0.02	0.03

NO_2^--N	NO_3^--N	NH_3-N	Cl^-	Sulfate	Cond	SRP	SiO_2	TRISCR	ALASCR
0.06	0.00	1.224	14.9	0.5	544	0.001	8.79	0.03	0.04
0.06	0.00	0.748	81.6	0.2	818	0.010	10.63	0.06	0.05
0.08	0.00	0.651	75.4	1.8	768	0.007	9.07	0.03	0.04
0.09	0.00	0.113	4.1	25.6	613	0.005	8.26	0.03	0.03
0.20	0.00	0.030	85.2	54.7	723	0.231	11.38	0.03	1.05
0.29	0.00	0.048	2.5	24.5	207	0.013	10.78	0.02	0.06
0.56	0.08	0.045	25.0	25.6	286	0.040	13.53	0.03	0.07
0.65	0.00	0.035	2.3	24.4	207	0.032	12.91	0.01	0.28
1.04	0.00	0.038	1.9	18.6	240	0.021	12.82	0.03	0.10
1.05	0.00	0.052	3.2	22.1	159	0.048	12.49	0.04	0.29
1.21	0.00	0.055	6.8	23.2	364	0.028	7.85	0.08	1.79
1.47	0.00	0.061	7.7	26.0	375	0.083	15.78	0.02	0.06
4.46	0.00	0.034	2.3	28.6	323	0.012	13.43	0.02	0.06
4.66	0.00	0.040	4.8	16.1	191	0.053	11.19	0.03	0.04
5.93	0.03	0.104	38.3	51.9	590	0.006	13.18	0.03	0.06
30.42	0.03	4.543	98.4	93.6	1198	0.049	11.77	0.06	0.68

Source: Heidelberg College Water Quality Laboratory.

NO_3^--N=Nitrate in mg/l
NO_2^--N=Nitrite in mg/l
NH_3-N=Unionized ammonia in mg/l
Cl^-=Chloride in mg/l
Sulfate=Sulfate in mg/l

Cond=Conductivity in µmhos/cm
SRP=Soluble reactive phosphorus in mg/l
SiO_2=Silicon dioxide in mg/l
TRISCR=Concentration of triazine-containing compounds in mg/l
ALASCR=Concentration of alachlor-containing compounds in mg/l

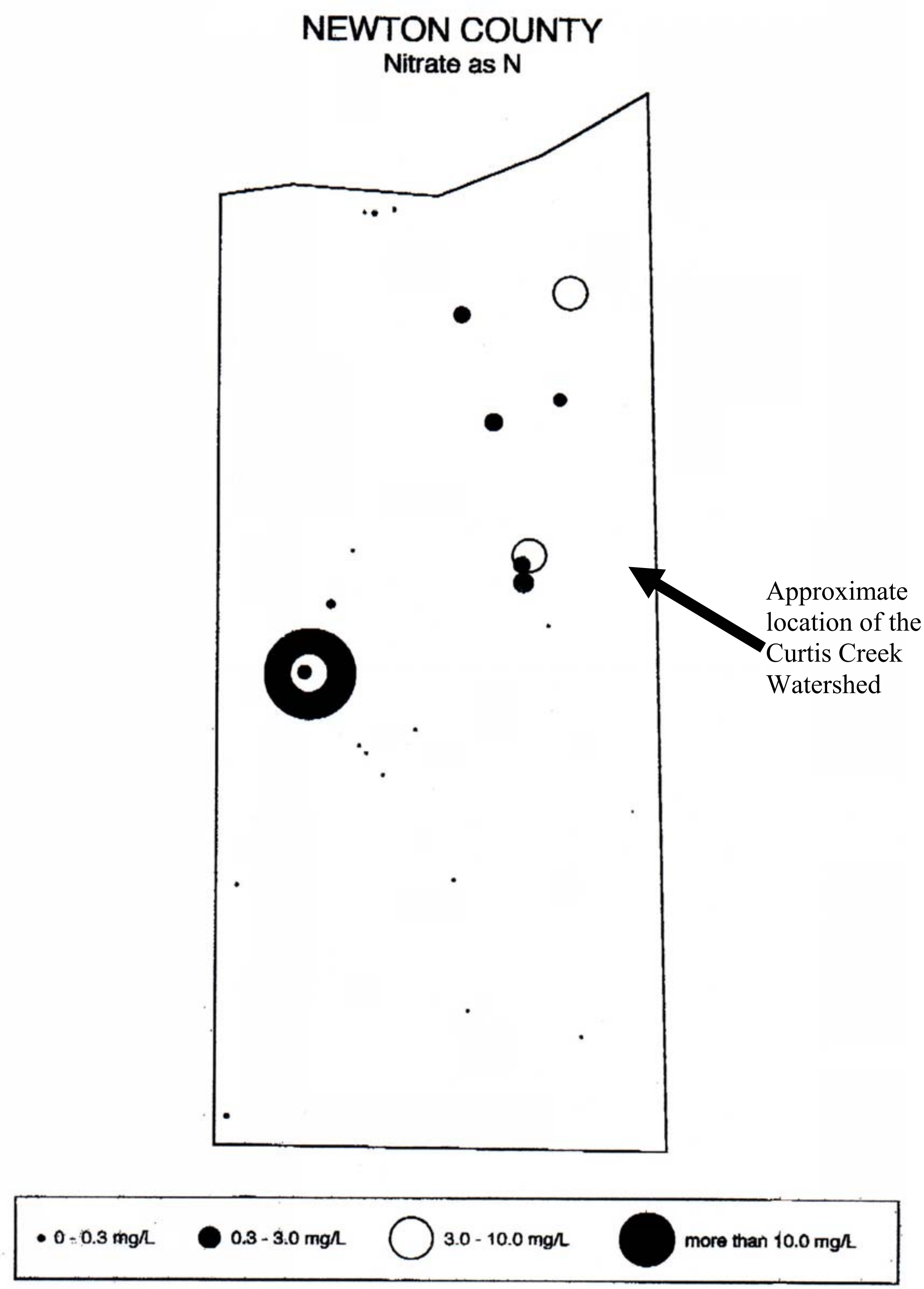


FIGURE 15. Relative nitrate-nitrogen concentration detected in groundwater well samples collected throughout Newton County. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of nitrate-nitrogen in that sample.

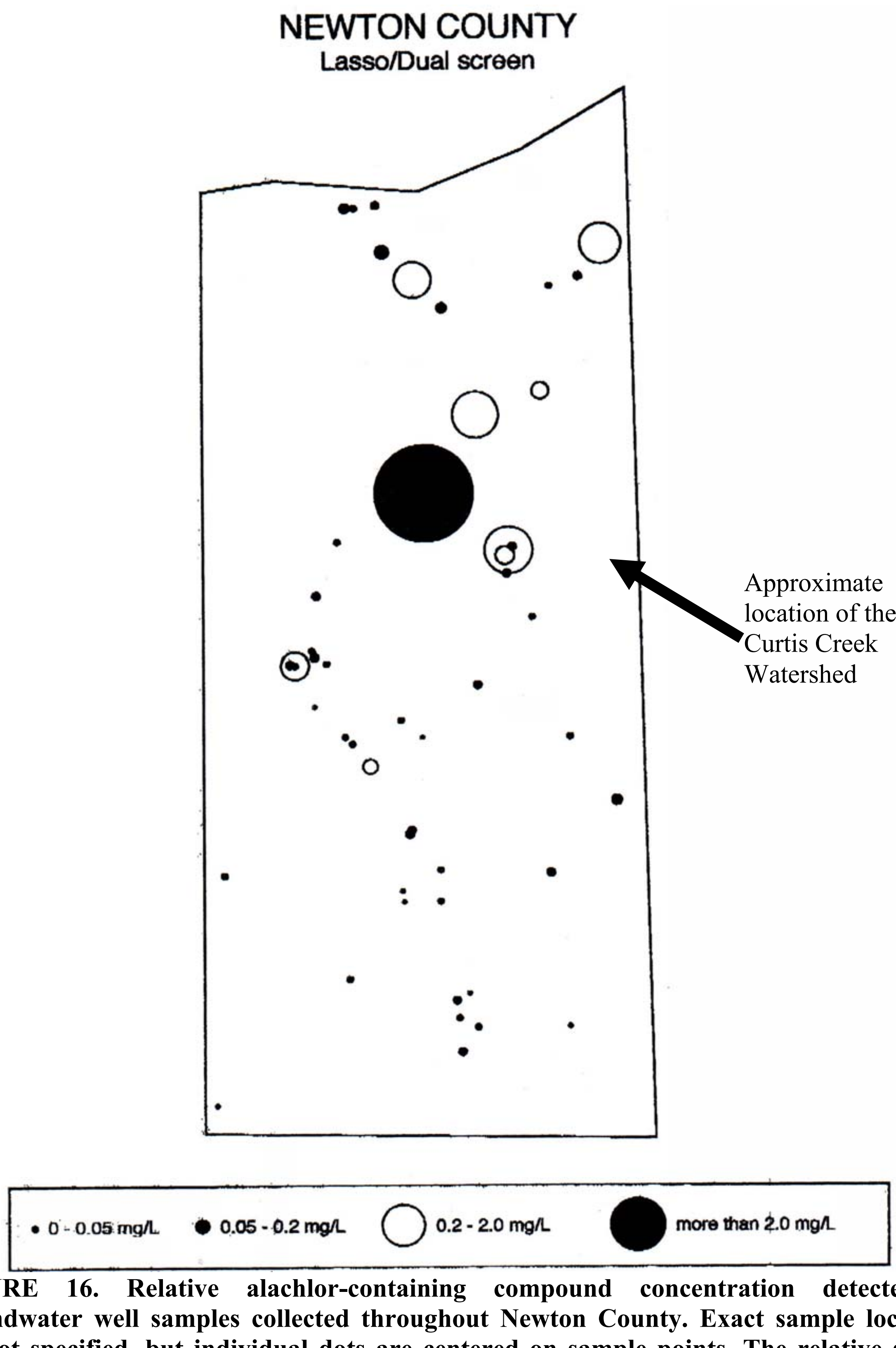


FIGURE 16. Relative alachlor-containing compound concentration detected in groundwater well samples collected throughout Newton County. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of alachlor-containing compounds in that sample.

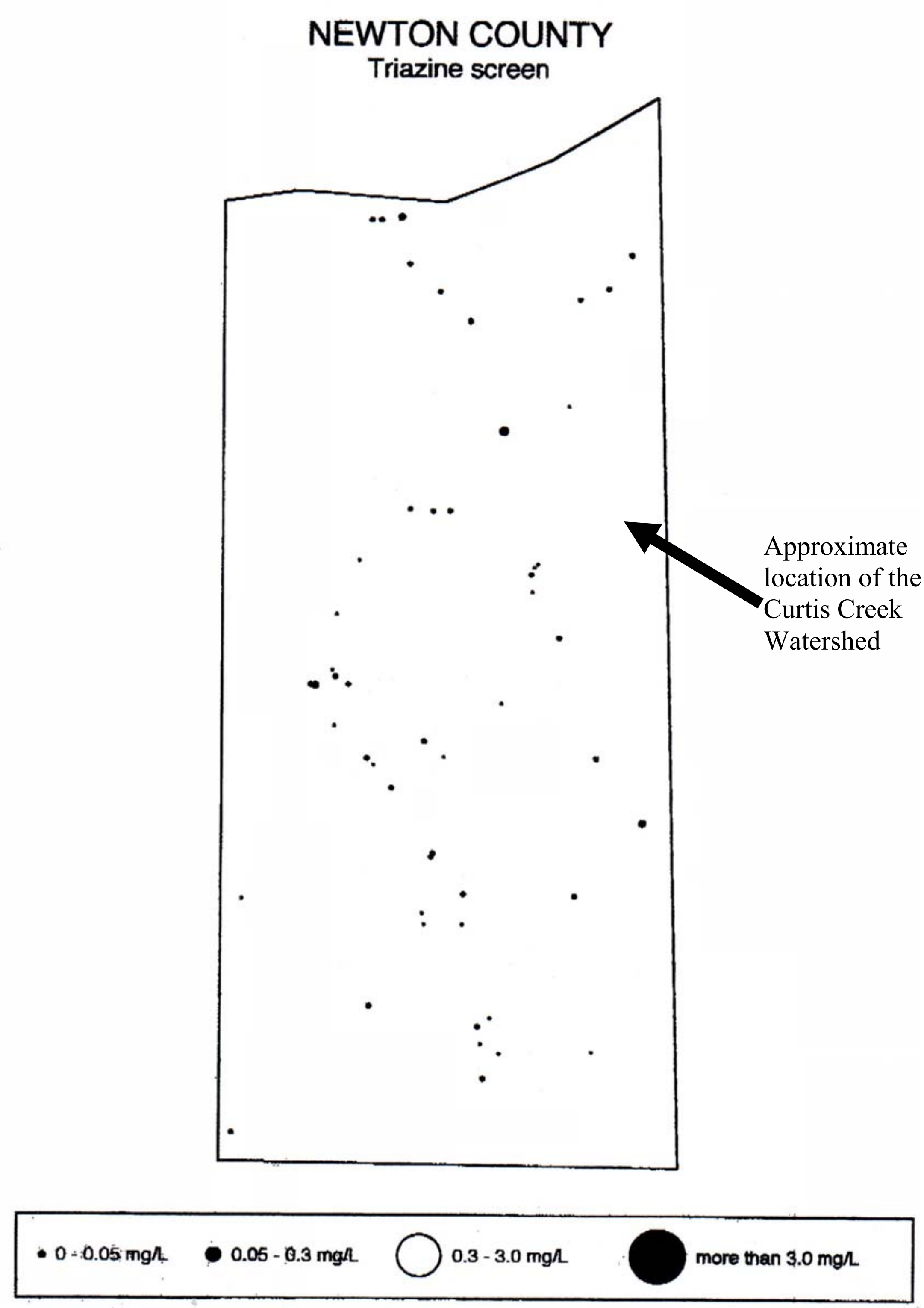


FIGURE 17. Relative triazine-containing compound concentrations detected in groundwater well samples collected throughout Newton County. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of triazine-containing compounds in that sample.

Table 27 presents the data collected by the CPWTP in Newton County during March 2003. Nitrate concentrations in the samples were below the national standard (10 mg/l) in all but three of the collected samples; concentrations exceeding the standard ranged from 12.94 mg/l to 25.26 mg/l. Figure 18 show the relative concentrations of nitrate-nitrogen in the samples. Like the 2002 samples, groundwater samples containing high nitrate-nitrogen concentrations generally occur in the central and northern potions of Newton County. Although there is moderate to high nitrate-nitrogen leaching potential, nitrate-nitrogen does not appear to be reaching groundwater wells throughout most of the county. However, two of the samples that exceeded the standard are in close vicinity to the Curtis Creek surface watershed. Chloride concentrations exceeded the national standard of 4 mg/l in 90% of the samples. Chloride concentrations ranged from 0.8-99.4 mg/l (median concentration 12.1 mg/l). Additional organic compound screening (ALASCR and TRISCR) was conducted on all of the forty-two samples and indicated the presence of pesticides or herbicides in the all but two of the drinking water well samples. Figures 19 and 20 display relative distributions for both the alachlor screen (ALASCR or Lasso/Dual) and the triazine screen (TRISCR), respectively. The screens indicate that an average concentration of 0.023 mg/l of organic, alachlor-containing compounds and 0.033 mg/l of organic, triazine-containing compounds were present in the well samples. ALASCR and TRISCR concentrations ranged from 0.0-0.039 mg/l and 0.0-2.98 mg/l, respectively. There is moderate to high pesticide leaching risk throughout the northern part of Newton County and low to moderate pesticide leaching risk throughout the southern portion of the county. Based on the CPWTP sampling results, pesticides do not appear to be reaching groundwater in most of the county; nonetheless, because pesticides are not normally present in private well samples collected in most areas, concentrations measured throughout Newton County are of concern (Water Quality Laboratory, 1996). (These and other parameters will be discussed in more detail in the Water Chemistry Methods Section.)

TABLE 27. Results of the Cooperative Private Well Testing Program conducted at forty-two locations throughout Newton County during March 2003.

NO_2^--N	NO_3^--N	NH_3-N	Cl^-	Sulfate	Cond	SRP	SiO_2	TRISCR	ALASCR
0.00	1.38	0.022	7.2	25.9	264	0.028	12.17	0.03	0.11
0.00	0.00	0.467	0.8	0.3	552	0.071	16.93	0.03	0.15
0.00	0.05	0.830	19.5	0.2	476	0.039	10.38	0.03	0.04
0.00	0.00	0.395	13.1	36.1	574	0.016	8.82	0.03	0.04
0.00	0.00	0.041	2.7	51.0	320	0.019	13.34	0.04	0.04
0.00	18.68	0.026	33.1	55.4	755	0.003	7.51	0.02	0.04
0.00	0.00	0.059	19.1	95.9	805	0.038	13.55	0.02	0.04
0.00	0.00	0.028	2.3	91.1	378	0.001	11.68	0.02	0.04
0.00	0.03	0.345	27.4	214.1	984	0.003	7.01	0.03	0.04
0.00	1.78	0.035	92.7	31.8	638	0.012	11.73	0.03	0.04
0.00	0.04	0.487	43.1	5.7	1150	0.002	6.99	0.02	0.05
0.00	0.20	0.038	81.5	47.1	691	0.213	10.43	0.03	0.32
0.00	0.00	0.040	8.3	51.4	450	0.012	9.30	0.03	0.08
0.00	2.22	0.022	2.4	15.8	247	0.020	14.99	0.03	0.06

NO_2^--N	NO_3^--N	NH_3-N	Cl^-	Sulfate	Cond	SRP	SiO_2	TRISCR	ALASCR
0.00	0.00	0.339	15.2	30.2	587	0.006	6.52	0.03	0.03
0.00	0.00	0.023	93.0	97.6	799	0.041	10.86	0.03	0.06
0.00	5.23	0.021	5.7	18.6	218	0.057	9.88	0.03	0.03
0.00	0.00	0.633	8.2	0.1	617	0.043	13.98	0.02	0.02
0.00	0.06	0.295	99.4	54.0	1177	0.009	7.28	0.02	0.02
0.00	0.04	0.458	16.6	0.4	450	0.041	8.80	0.03	0.02
0.00	12.94	0.017	8.7	19.9	338	0.452	12.61	0.07	0.06
0.00	0.22	0.411	19.2	0.6	490	0.023	8.41	0.02	0.03
0.00	0.00	0.064	14.7	86.0	467	0.009	11.84	0.02	0.09
0.00	0.04	0.446	16.5	192.4	804	0.016	9.92	0.02	0.03
0.00	0.44	0.001	7.2	56.1	363	0.016	16.76	0.03	1.61
0.00	0.83	0.009	6.4	30.0	293	0.038	10.69	0.02	0.04
0.08	2.04	0.008	14.2	42.8	286	0.015	12.63	0.02	0.03
0.00	0.00	1.443	7.2	8.0	591	0.171	14.77	0.02	0.03
0.00	0.03	1.714	28.3	0.1	559	0.095	10.01	0.02	0.05
0.00	0.00	0.007	6.4	49.0	306	0.008	8.91	0.02	1.08
0.00	0.00	0.293	7.3	0.1	690	0.006	6.65	0.02	0.03
0.00	0.00	0.597	3.8	31.6	545	0.049	16.20	0.02	0.04
0.00	0.00	5.306	7.5	6.0	679	0.322	9.30	0.02	0.03
0.00	0.03	0.565	14.7	15.2	514	0.040	9.49	0.02	0.04
0.00	0.03	0.660	27.0	14.9	544	-0.004	7.18	0.02	0.04
0.00	0.03	0.211	13.7	27.7	552	-0.002	8.80	0.02	0.03
0.00	25.26	-0.004	12.2	17.5	420	0.016	14.37	0.03	2.98
0.00	0.00	-0.002	4.2	57.0	308	0.004	9.64	0.03	0.09
0.00	0.23	0.003	1.2	18.0	76	0.011	15.30	0.02	0.04
0.00	0.04	0.082	12.0	59.2	381	0.001	8.47	0.02	0.62
0.00	0.76	0.019	7.7	46.9	302	0.011	14.56	0.00	0.00
0.00	0.00	0.240	9.5	1.7	577	0.038	9.45	0.00	0.00

Source: Heidelberg College Water Quality Laboratory.

NO_2^--N=Nitrate in mg/l
NO_3^--N=Nitrite in mg/l
NH_3-N=Unionized ammonia in mg/l
Cl^-=Chloride in mg/l
Sulfate=Sulfate in mg/l
Cond=Conductivity in μmhos/cm
SRP=Soluble reactive phosphorus in mg/l
SiO_2=Silicon dioxide in mg/l
TRISCR=Concentration of triazine-containing compounds in mg/l
ALASCR=Concentration of alachlor-containing compounds in mg/l

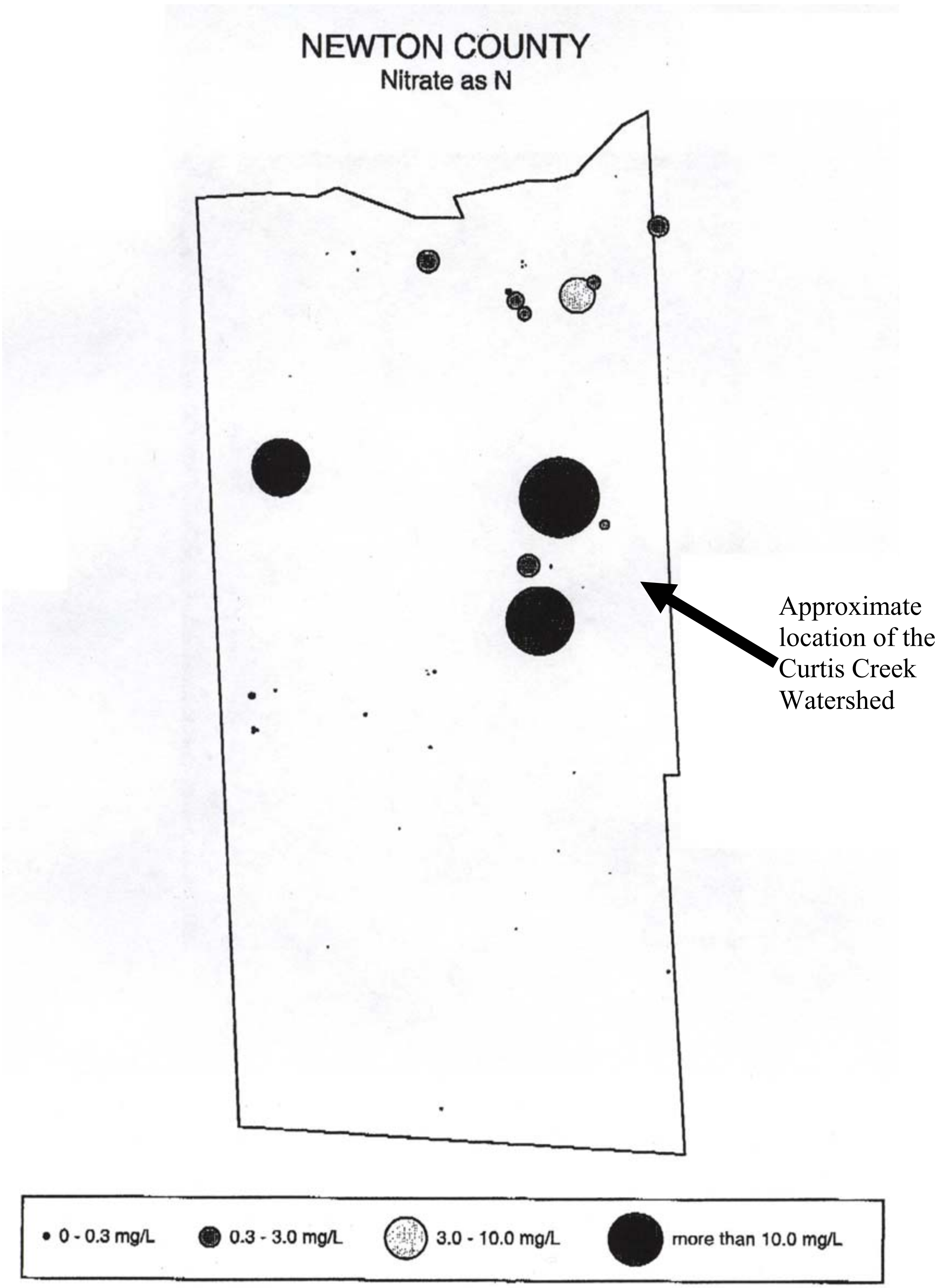


FIGURE 18. Relative nitrate-nitrogen concentration detected in groundwater well samples collected throughout Newton County in March 2003. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of triazine-containing compounds in that sample.

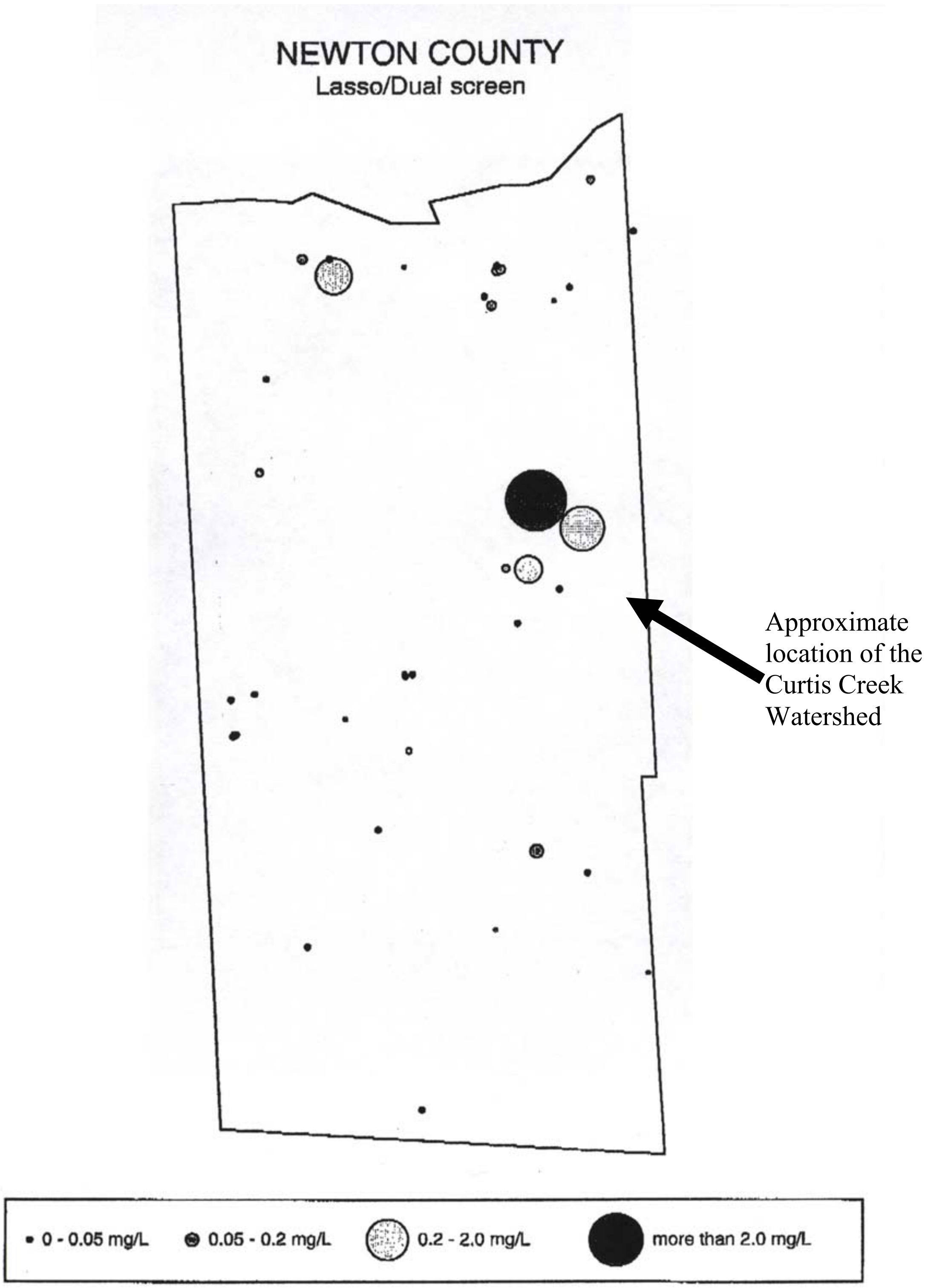


FIGURE 19. Relative alachlor-containing compound concentrations detected in groundwater well samples collected throughout Newton County in March 2003. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of triazine-containing compounds in that sample.

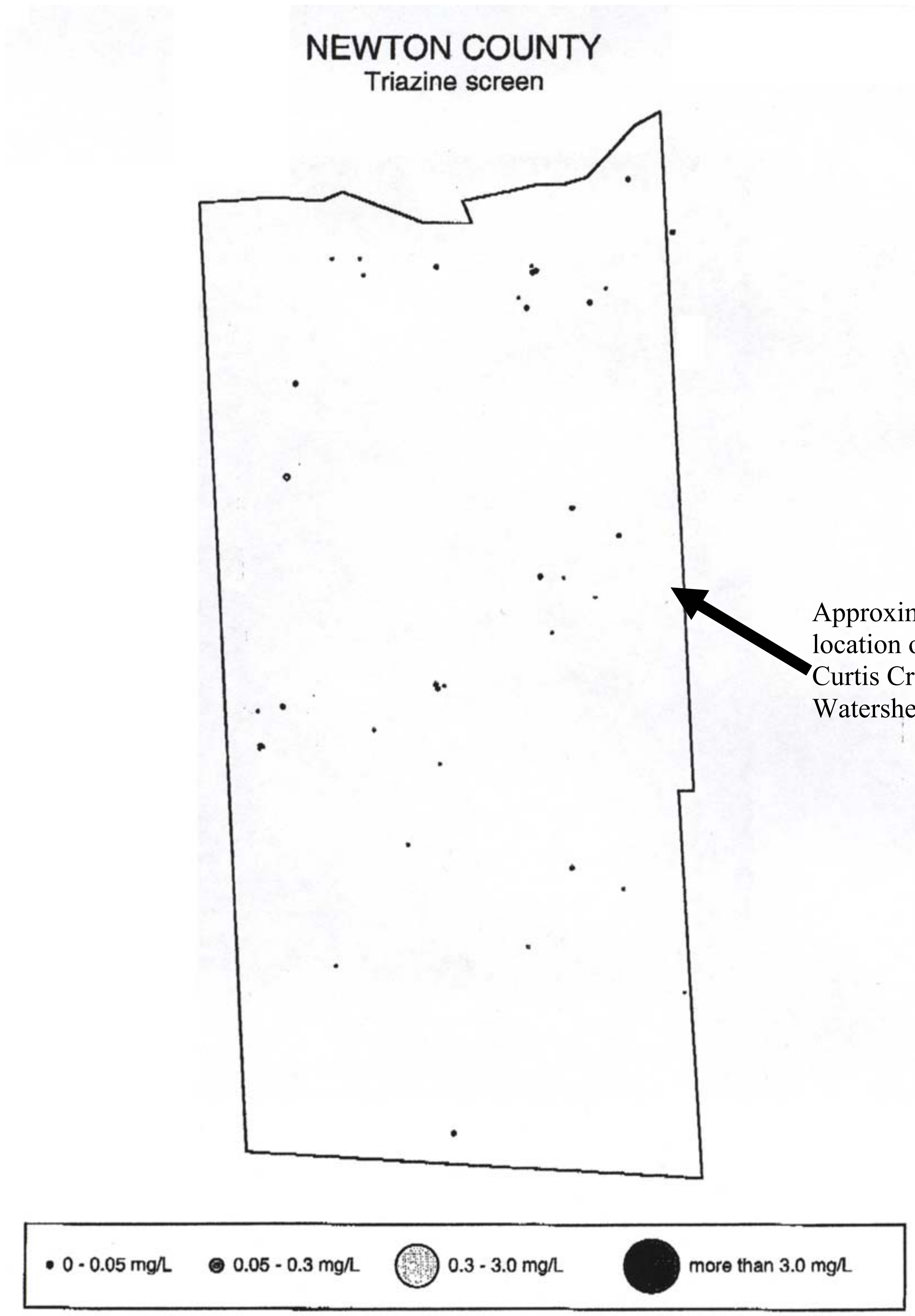


FIGURE 20. Relative triazine-containing compound concentrations detected in groundwater well samples collected throughout Newton County in March 2003. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of triazine-containing compounds in that sample.

Stream Chemistry Studies

Introduction

Stream chemistry studies have been conducted in or near the study area by IDEM, the Newton County Health Department (NCHD), the Jasper County Health Department (JCHD), a local landowner, the United States Geological Survey (USGS), and Hoosier Riverwatch volunteers. IDEM assessed water chemistry in Curtis Creek and the Iroquois River at nine sites (Figure 21) in the fall of 2000. The NCHD tested for *E. coli* at eleven sites in vicinity of or in the Curtis Creek Watershed during the years of 2000 through 2001 (Figure 21). The JCHD collected *E. coli* samples in two locations along Curtis Creek in 2002 (Figure 21). Mike Zickmund collected samples from four sites in the northern portion of the Curtis Creek Watershed from 2000 to 2001 (Figure 21). The Fair Oaks Dairy collected water quality samples in conjunction with sampling conducted during this study at two locations in 2002 (Figure 21). The USGS assessed sediment and sediment-related parameters at their gauging station on the Iroquois River from 1968 to 1980 and sampled *E. coli* and turbidity at three locations in 1999 (Figure 21). Hoosier Riverwatch volunteers sampled the Iroquois River at three locations from 1997 to 2000 (Figure 21). Due to the relative lack of historical data, trend analysis was not possible. (Please see the Water Chemistry Methods Section for a more detailed description of water quality parameters.)

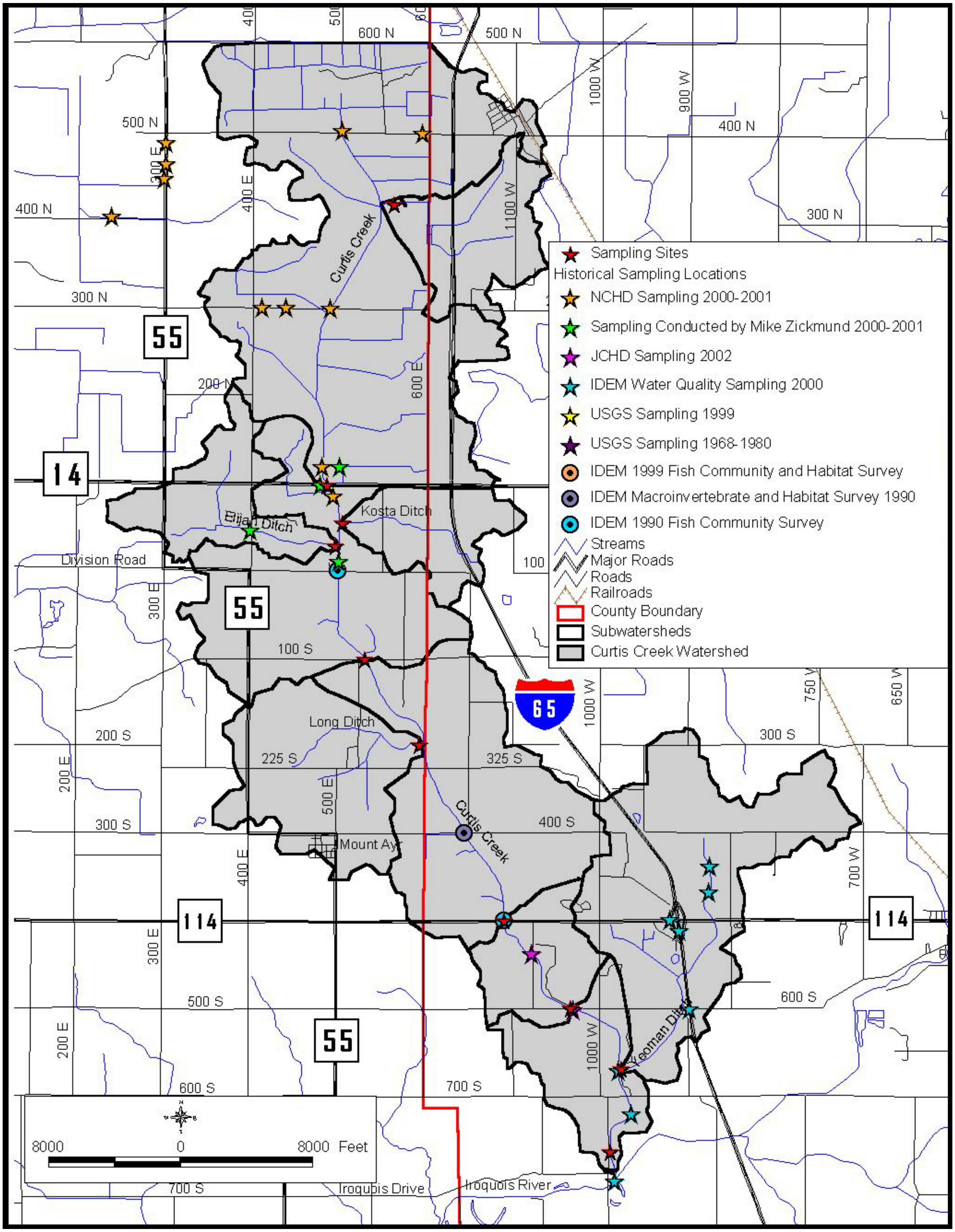


FIGURE 21. Historical stream chemistry, habitat, macroinvertebrate, and fish community survey locations.

IDEM Study

Sites on Curtis Creek and Yeoman Ditch sampled by IDEM for stream chemistry in 2000 are close in proximity to Sites 1 and 2 sampled during the current study. Tables 28 and 29 present the data collected by IDEM October 17, 2000. The dissolved oxygen concentration in the McDonald's WWTP outfall was below the concentration range (3-5 mg/l) required to sustain fish and other aquatic organisms. Conductivity measurements at all sites except Curtis Creek, Unnamed Tributary 1, and the Iroquois River were higher than expected values for this region of Indiana (1000-1360 μmhos/cm); both Grandma's and Trail Tree WWTP outfall also possessed extremely high conductivity levels (Allan, 1995). All BOD levels exceeded the typical Indiana range of 1.1-3.3 mg/l (White, unpublished). Grandma's and Trail Tree outfalls contained chloride concentrations greater than 1000 mg/L, which could be deleterious to aquatic fauna (Crowther and Hynes, 1977). Nitrate-nitrogen concentrations at McDonald's, Grandma's, Trail Tree, and Unnamed Tributary 2 exceeded the Indiana Administrative Code (IAC) drinking water standard of 10 mg/l. (IAC standards are applied to waterbodies outside of the mixing zone. Outfalls are not outside the mixing zone, but IAC standards are included here as reference points.) Ammonia-nitrogen concentrations for all samples except the Iroquois River were greater than the IAC maximums for the respective pH and temperature of water from the outfalls. Total phosphorus concentrations at all sites except Yeoman Ditch (private road), Curtis Creek, and the Iroquois River exceeded the typical Indiana range of 0.01-0.17 mg/l (White, unpublished). (IAC standards and parameters will be discussed in more detail in the Water Chemistry Methods Section).

TABLE 28. Curtis Creek stream chemistry data gathered at nine sites by IDEM on October 17, 2000. Data marked with an asterisk (*) were collected August 22, 2000.

Site	DO	% Sat	pH	Temp	Cond	Alk	Hard	BOD	COD	Cl^-	TOC
Iroquois River (CR 1000W)	10.1*	100.9*	8.9*	24.0*	690*	210	100	--	6.6	65	5.8
McDonalds WWTP Outfall	2.2	21.8	6.5	14.7	1675	60	160	5.0	44	320	12
Unnamed Tributary 1 (SR 114)	9.9	100.7	7.9	15.1	910	270	420	3.4	18	86	4.5
Grandma's WWTP Outfall	5.7	64.6	7.6	20.1	3490	250	300	7.5	22	1000	6.3
Trail Tree WWTP Outfall	7.2	79.1	7.7	18.3	3640	280	400	4.7	11	1300	4.2
Unnamed Tributary 2 (SR 114)	5.1	53.8	8.0	17.0	1101	280	450	5.0	25	690	4.0
Yeoman Ditch (CR 600 S)	5.3	55.4	7.6	16.4	1100	280	450	5.0	15	150	5.8
Yeoman Ditch (private road)	8.0	82.0	7.9	15.3	1116	280	460	4.6	17	140	6.7
Curtis Creek (700 S)	8.9	90.9	7.9	15.3	608	190	300	4.3	16	35	5.1

Source: Chuck Bell, IDEM Data Group
DO=Dissolved Oxygen in mg/l
%Sat=Percent Oxygen saturation in water sample
Temp=Temperature in ◦C
Cond=Conductivity in μmhos/cm
Alk=Alkalinity in mg/l
Hard=Hardness (as H_2CO_3) in mg/l
BOD=Biochemical Oxygen Demand in mg/l
COD=Chemical Oxygen Demand in mg/l
Cl^-=Chlorides in mg/l
TOC=Total organic carbon in mg/l

TABLE 29. Curtis Creek stream chemistry data gathered at nine sites by IDEM on October 17, 2000.

Site	NO_3^--N	NH_3-N	TKN	TP	TSS	TS	TDS
Iroquois River (CR 1000W)	0.26	0.16	0.56	0.16	10	480	460
McDonalds WWTP Outfall	67	0.43	1	3.3	16	1300	1,100
Unnamed Tributary 1 (SR 114)	4.3	0.4	1.6	0.38	10	720	550
Grandma's WWTP Outfall	28	0.65	1.8	2.1	25	2300	2,000
Trail Tree WWTP Outfall	11	0.41	2.2	2.7	43	2800	2,400
Unnamed Tributary 2 (SR 114)	12	0.76	3.4	2.1	39	1900	1,700
Yeoman Ditch (CR 600 S)	0.38	0.47	2.4	0.28	11	820	700
Yeoman Ditch (Buckham Rd)	0.56	0.26	1.7	0.15	10	850	730
Curtis Creek (700 S)	0.14	0.28	1.5	0.033	7	510	390

Source: Chuck Bell, IDEM Data Group
NO_3^--N=Nitrate in mg/l
NH_3-N=Unionized Ammonia in mg/l
TKN=Total Kjeldahl Nitrogen in mg/l
TP=Total Phosphorus in mg/l
TSS=Total Suspended Solids in mg/l
TS=Total Solids in mg/l
TDS=Total Dissolved Solids in mg/l

NCHD Study

The NCHD sampled seven sites in the northern portion of the Curtis Creek Watershed in 2000 and 2001. (NCHD collected samples from a total of eleven sites. Four of these sites were located in the adjacent watershed.) Although these samples were not collected at any of the current study sampling sites, they were collected near Sites 9 and 10 of the current study. According to the NCHD data (Table 30), *E. coli* concentrations in the Curtis Creek Watershed ranged from 1-140 colonies/100 ml (1-20,000 col/100 ml in all samples). Measured concentrations exceeded the Indiana state standard of 235 col/100 ml in three of the eleven sites, all of which were located in an adjacent watershed. (Again, standards and parameters will be discussed in more detail in the Water Chemistry Methods Section.)

TABLE 30. Newton County Health Department data. Samples marked with an asterisk (*) were collected from a tributary to Mud Lake Ditch which lies in the watershed that is adjacent to the Curtis Creek Watershed.

Site	Date	*E. coli*
CR 500 N west of CR 600 E	3/7/2000	16
North of SR 14	8/7/2000	140
SR 14	8/7/2000	89
CR 300 N and CR 500 E	8/18/2000	7
East of CR 500 E on CR 300 N	8/18/2000	35
SR 55 north of CR 400 N*	2/8/2001	20,000
SR 55 north of CR 400 N (east side)*	2/8/2001	17,000
CR 300 N	2/13/2001	1
CR 400 N*	2/13/2001	15
CR 500 E at South Entrance	2/13/2001	27
SR 55 north of CR 400 N*	2/25/2001	960

Source: Ruth Ellen Haywood, Newton County Health Department
E. coli=*E. coli* in colonies/100 ml

JCHD Study

The JCHD sampled Curtis Creek upstream and downstream of the Curtis Creek Country Club in 2002. The two sites generally correspond with water quality collection sites sampled during this study; the JCHD sampling site upstream of the Curtis Creek County Club is located near Site 4 of the current study, while the JCHD sampling site downstream of the Curtis Creek County Club is located near Site 3. According to the JCHD data (Table 31), *E. coli* concentrations in the Curtis Creek Watershed ranged from 770-1400 colonies/100 ml. Measured concentrations exceeded the Indiana state standard of 235 col/100 ml in samples collected at both sites. (Again, standards and parameters will be discussed in more detail in the Water Chemistry Methods Section.)

TABLE 31. Jasper County Health Department data.

Site	Date	*E. coli*
CR 1074 West	7/12/2002	770
East of CR 600 South	7/12/2002	1400

Source: Sandra Parks, Jasper County Health Department
E. coli=*E. coli* in colonies/100 ml

Local Landowner Data

A local landowner, Mike Zickmund, collected water samples in the northern portion of the Curtis Creek Watershed at four sites in 2000 and 2001. Mr. Zickmund's State Road 14 sampling site corresponds with Site 9; the other three sampling sites are located either upstream or downstream of the sampling locations of the current study. Mr. Zickmund's data shows that *E. coli* concentrations in the streams he sampled ranged from 2-1,300 colonies/100 ml (Table 32). Measured concentrations were below the Indiana state standard of 235 col/100 ml for all samples except the August sample collected at Division Road. (Again standards and parameters will be discussed in more detail in the Water Chemistry Methods Section.)

TABLE 32. Water quality data collected by Mike Zickmund in the northern portion of the Curtis Creek Watershed.

Site	Date	*E. coli*	Total Coliform
Curtis Creek—State Road 14	1/18/00	20	--
Curtis Creek—Division Road	2/24/00	98	--
	8/17/00	1,300	--
Elijah Ditch—CR 400 E	8/17/00	73	--
	3/26/01	2	816
Unnamed Ditch—State Road 14	3/26/01	49	1,414

Source: Mike Zickmund, local landowner.
E. coli=*E. coli* in colonies/100 ml
Total coliform=Total coliform in colonies/100 ml

Fair Oaks Dairy Data

The Fair Oaks Dairy collected water quality samples in conjunction with sampling conducted during the 2002 Curtis Creek Watershed Diagnostic Study. Samples were collected from two sites located where Curtis Creek crosses State Road 14 (Site 9) and at an unnamed tributary on

Fair Oaks Dairy property (Site 10). (These sites are indicated by the two northernmost red stars in Figure 21.) Nitrate-nitrogen concentrations exceeded the Ohio EPA standard for the protection of aquatic life (1.6 mg/l) at both sites on all three dates. During the July sample, nitrate-nitrogen exceeded the Indiana state standard of 10 mg/l (Table 33). Ammonia-nitrogen and total phosphorus concentrations were also high; concentrations did not exceed either Indiana state standards or Ohio EPA standards. *E. coli* concentrations exceeded the Indiana state standard of 235 colonies/100 ml on only one occasion (July 2002; 2000 col/100 ml). (Again, standards and parameters will be discussed in more detail in the Water Chemistry Methods Section.)

Table 33. Fair Oaks Dairy water quality data.

Site	Date	NO_3-N	NH_3-N	TP	*E. coli*
Curtis Creek at SR 14	5/14/2002	1.56	1.8	0.21	170
	6/25/2002	4.5	0.3	0.27	--
	7/30/2002	4.5	<0.10	0.27	140
Unnamed Tributary to Curtis Creek	5/14/2002	8.7	<0.10	<0.10	78
	6/25/2002	8.5	0.172	0.16	--
	7/30/2002	14.4	0.17	0.16	2,000

Source: Fair Oaks Dairy.
NO_3-N=Nitrate-nitrogen in mg/l
NH_3-N=Ammonia-nitrogen in mg/l
TP=Total phosphorus in mg/l
E. coli=Escherichia coli in colonies/100 ml

USGS Study

The USGS measured sediment and discharge on numerous dates from 1968 and 1980 at their gauging station near Foresman on the Iroquois River (Figure 21). During each sampling event, particles smaller than 0.062 mm in diameter consistently composed more than 92% of the sample (Table 34). This suggests that clays and/or fine silts dominated the sediment load in the Iroquois River. Temperatures followed a normal seasonal pattern with none of the recorded temperatures exceeding the state standard (Table 35). Sediment loading rates ranged from close to 2 up to 1,520 tons/day (Table 35). Sediment concentration in samples measured as total suspended solids (TSS) was not directly correlated with discharge rate, and the relationship was not statistically significant (Figure 22; r^2=0.006; p=0.53). It is important to note that although a linear relationship does not describe the data (r^2=0.006), non-linear regression was not performed, and a non-linear equation may fit the data better.

TABLE 34. Results of USGS fractionation of sediment carried in Iroquois River stream water on four dates from 1968 to 1976.

Date	Particle Size	% of Sediment in Sample Smaller than Listed Size
7/10/68	<0.002	31
7/10/68	<0.004	43
7/10/68	<0.008	58
7/10/68	<0.016	79
7/10/68	<0.031	88
7/10/68	<0.062	92
7/10/68	<0.125	96
7/10/68	<0.250	100
4/24/73	<0.002	91
4/24/73	<0.004	94
4/24/73	<0.008	97
4/24/73	<0.016	98
4/24/73	<0.031	99
4/24/73	<0.062	99
4/24/73	<0.125	100
5/22/74	<0.002	77
5/22/74	<0.004	90
5/22/74	<0.008	96
5/22/74	<0.016	97
5/22/74	<0.031	98
5/22/74	<0.062	99
5/22/74	<0.125	99
5/22/74	<0.250	100
2/18/76	<0.002	78
2/18/76	<0.004	90
2/18/76	<0.008	96
2/18/76	<0.016	97
2/18/76	<0.031	98
2/18/76	<0.062	99
2/18/76	<0.125	99
2/18/76	<0.250	100

Source: USGS website (http://www.usgs.gov).
Particle size=Particle size in mm

TABLE 35. Iroquois River temperature and sediment loading data collected by the USGS near Foresman from 1968 to 1980.

Date	Temperature	Discharge	TSS	TSS Load
7/10/68	22	299	87	70
7/10/68	22.5	296	78	62
8/28/68	19	82	134	30

Date	Temperature	Discharge	TSS	TSS Load
10/10/68	13.5	55	110	16
1/31/69	3	3,080	112	931
2/12/69	1	380	75	77
5/8/69	19	327	123	109
6/26/69	25	362	115	112
8/19/69	26	76	148	30
10/7/69	16.5	45	99	12
11/26/69	6	488	84	111
1/16/70	0	88	96	23
3/4/70	6	379	76	78
4/14/70	9	460	46	57
4/22/70	10	2,790	70	527
5/26/70	20.5	660	182	324
7/22/70	21	126	124	42
8/21/70	22.5	30	148	12
9/30/70	15.5	598	53	86
3/11/71	1.5	311	128	107
4/15/71	10	218	140	82
6/22/71	22.5	229	205	127
7/28/71	20	67	208	38
10/6/71	--	128	112	39
11/11/71	--	68	520	9.5
12/21/71	--	837	17	38
3/16/72	--	917	29	72
3/29/72	5	424	24	27
4/21/72	--	1180	51	162
5/3/72	15	432	79	92
6/7/72	20	246	88	58
7/21/72	24	584	62	98
8/14/72	23	1,140	44	135
9/21/72	20	238	98	63
11/9/72	9.5	701	36	68
12/21/72	6	637	9	15
1/30/73	2	831	37	83
3/13/73	8	1,240	29	97
4/24/73	14.5	2,740	74	547
6/5/73	19	821	99	219
11/16/73	10	70	24	4.5
12/15/73	2	178	26	12
1/19/74	0	622	46	77
5/22/74	19	2,480	149	998
6/25/74	18	575	86	134
5/3/75	11	573	49	76

Date	Temperature	Discharge	TSS	TSS Load
7/21/75	--	197	154	82
2/18/76	2	2,930	192	1,520
3/24/76	10	436	54	64
4/28/76	12	736	41	82
6/24/76	19	997	90	242
7/1/76	19	997	77	207
9/15/76	21.5	44	88	10
10/20/76	7	53	12	1.7
11/23/76	0.5	41	16	1.8
4/6/77	6	737	12	24
5/4/77	--	504	48	65
6/15/77	18	96	71	18
7/14/77	--	62	106	18
8/26/77	--	65	87	15
1/12/78	0	135	108	39
3/28/78	--	1,810	17	83
9/23/80	19	364	52	51

Source: USGS website (http://www.usgs.gov)
Temperature=Temperature in degrees Celsius
Discharge=discharge in cubic feet per second (cfs)
TSS=Total suspended solids in mg/l
TSS Load=Total suspended solids load in tons/day

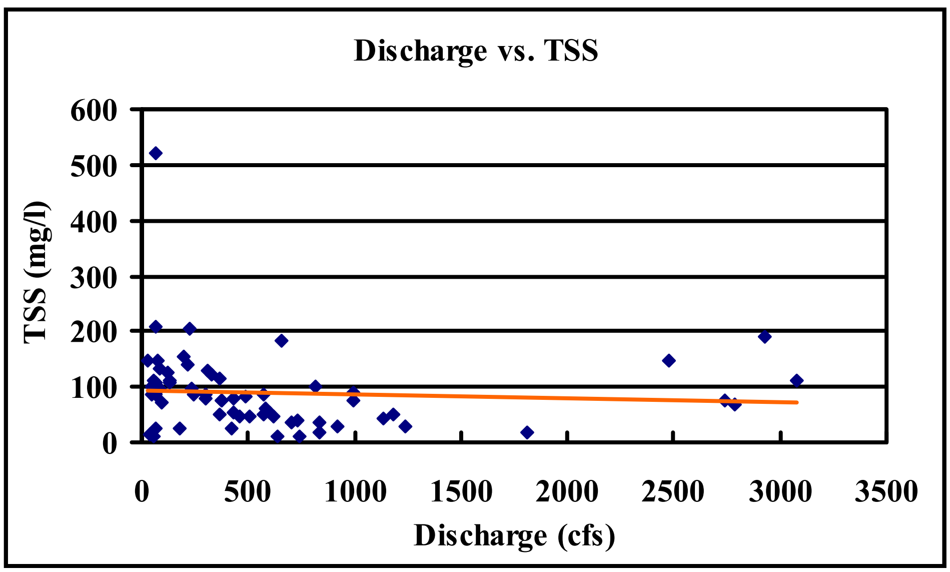


FIGURE 22. Non-statistically significant relationship between total suspended solids (TSS) and discharge as sampled by the USGS from 1968 to 1980.

The USGS also measured several stream parameters including turbidity and *E. coli* five times at three locations on the Iroquois River in 1999 (Figure 23). Temperature, pH, dissolved oxygen, and conductivity were all within ranges appropriate for supporting warmwater aquatic life. *E. coli* concentrations exceeded the state standard for single samples (235 colonies/100 ml) at the

US 231 and Rensselaer sites in three of the five samples; concentrations exceeded the standard in four of the five samples at Foresman (Table 36). The state standard for five-sample geometric means (125 colonies/100 ml) was also exceeded at each of the three sites (Figure 23). Silcox et al. (2001) noted that turbidities greater than 83 NTU often correlated with *E. coli* concentrations in excess of the state standard for single samples. This statistically significant relationship ($p<0.001$) holds for all samples collected in the Kankakee and Lower Wabash River Watersheds indicating that runoff is one of the main factors affecting *E. coli* concentrations. However, turbidity concentrations less than 83 NTU did not always result in *E. coli* concentrations lower than 235 colonies/100 ml, which indicates that other environmental and anthropogenic factors are also responsible for the elevated *E. coli* concentrations (Silcox et al., 2001).

TABLE 36. Iroquois River stream chemistry data collected at three locations by the USGS.

	Date	Discharge	Temp	pH	DO	Cond	Turb	*E. coli*
Iroquois River (US 231)	6/30/1999	--	21.0	7.9	9.1	529	13	630
	7/7/1999	--	23.5	7.9	9.1	545	10	670
	7/14/1999	--	20.5	8.0	9.4	512	7	77
	7/21/1999	--	24.5	7.4	8.1	503	14	<5
	7/28/1999	--	25.5	7.9	6.2	524	4	730
Iroquois River (Rensselaer)	6/30/1999	113	21.5	7.8	7.4	550	20	690
	7/7/1999	93	24.5	7.8	7.4	570	20	670
	7/14/1999	35	21.0	7.9	7.7	562	13	93
	7/21/1999	57	24.5	7.7	6.1	504	23	190
	7/28/1999	32	26.0	7.9	4.4	566	20	840
Iroquois River (Foresman)	7/1/1999	140	21.6	7.8	7.0	554	49	3,600
	7/8/1999	257	24.5	7.9	6.8	609	26	870
	7/15/1999	54	22.5	8.0	6.4	635	21	230
	7/22/1999	143	25.5	7.7	5.6	449	27	1,200
	7/29/1999	58	27.0	7.8	4.6	644	31	1,800

Source: Silcox et al., 2001.
Discharge=Stream Flow in cubic feet per second (cfs)
Temp=Temperature in degrees Celsius
Cond=Conductivity in µmohs/cm
Turb=Turbidity in Nephelometric Turbidity Units (NTUs)
E. coli=*E. coli* in colonies/100 milliliters

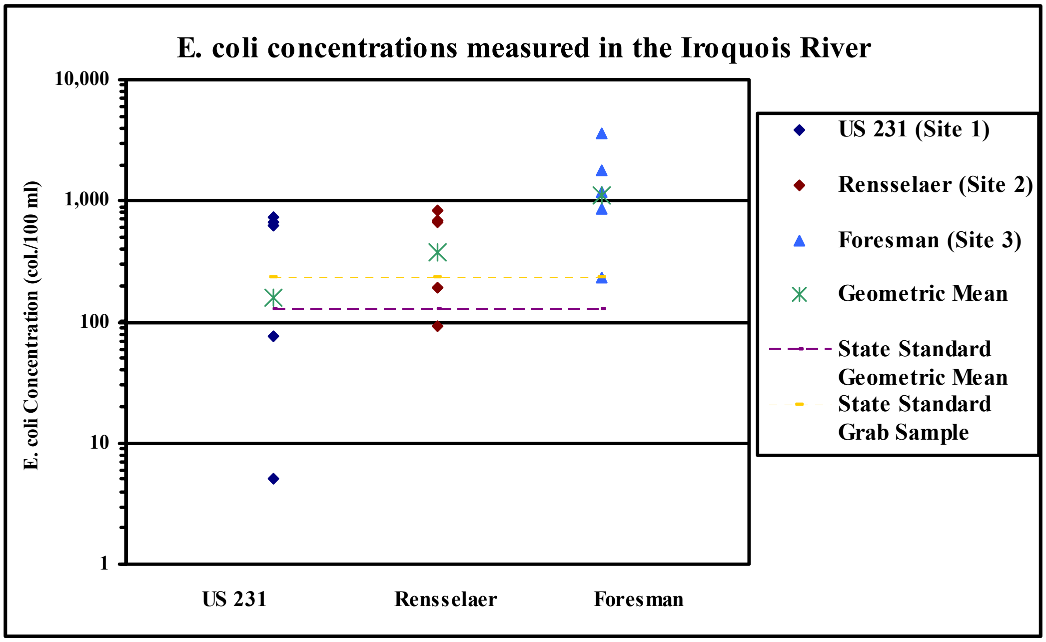


FIGURE 23. Concentrations of *E. coli* and five-sample geometric means for three locations along Iroquois River.

Hoosier Riverwatch Study

Hoosier Riverwatch volunteers sampled three sites on the Iroquois River. These sites were both upstream and downstream of the Curtis Creek confluence with the Iroquois River. They do not correspond with any sites sampled during this study. Participating volunteer groups measured nine different water quality parameters as described by the Hoosier Riverwatch guidelines (White, unpublished). Data for each parameter was assigned a quality value, and a Water Quality Index (WQI) for the site was then calculated by summing the individual parameter values. Table 37 contains data from the study.

TABLE 37. Iroquois River water chemistry data and WQI values gathered at three sites by Hoosier Riverwatch volunteers. A WQI score of 90-100% indicates excellent, 70-90% good, 50-70% medium, 25-50% bad, and 0-25% very bad water quality (Rouch, 2000).

Site	Date	DO	FC	pH	BOD	Temp Δ	TP	NO_3^-	Turb	TS	WQI
Iroquois River (SR 114)	10/1/1997	12	300	8.7	2	0	0	0.88	48	5	77
	10/2/1997	8.8	100	8.5	4	0	0	13.2	48	3	74.23
	10/23/1998	9	132	7.3	1	1	0	2	4	--	79.02
Iroquois River (CR 1200 S)	3/30/1998	9	83776	8.1	1	1	0	5	5.7	300	62.08
	4/24/1998	--	>100,000	8.8	4	0	13	6.5	22	60	41.88
Iroquois River (SR 16)	3/23/2000	9.8	--	--	--	8.8	0	0	--	--	--

Source: Lyn Hartman, Hoosier Riverwatch
DO=Dissolved Oxygen in mg/L
FC=Fecal Coliform in cfu/100 ml (cfu=colony forming units)
BOD=Biological Oxygen Demand in mg/L
Temp Δ=Change in temperature over a given stream length
TP=Total Phosphorus in mg/L
NO_3-N=Nitrate-nitrogen in mg/L
Turb=Turbidity in nephelometric turbidity units
TS=Total solids in mg/L
WQI=Water Quality Index

IDEM 303(d) List

Once every two years, IDEM publishes the 305(b) report which documents the status of water quality in the State of Indiana. The 305(b) report includes the 303(d) list which names the "impaired waterbodies" that will be targeted for Total Maximum Daily Load (TMDL) development in the future. Yeoman Ditch and Curtis Creek (from its confluence with Yeoman Ditch to its confluence with the Iroquois River) are included on the 303(d) list for possessing low dissolved oxygen concentrations and high nutrient, total dissolved solids, and chloride levels (IDEM, 2002; Figure 24). (Tables 28 and 29 contain water quality data collected by IDEM in 2000 which exceed state standards and recognized average values for nitrate-nitrogen, ammonia-nitrogen, total phosphorus, BOD, chlorides, and total dissolved solids.) Additionally, *E. coli* and polychlorinated biphenyls (PCBs) currently impair the water quality of the Iroquois River, which also appears on the 303(d) list (Figure 24). Because previous studies have shown elevated concentrations of *E. coli* at sites throughout the watershed, this parameter is of concern in the entire Curtis Creek Watershed.

FIGURE 24. 303(d) listed waterbodies in the Iroquois River Basin. All bodies of water are displayed on the map. Those waterbodies included on the 303(d) list are highlighted in pink.

<u>Macroinvertebrate Community and Habitat Studies</u>

IDEM also assessed water quality within the study watershed using macroinvertebrate analyses. The IDEM study included collection of habitat data as well for one site on Curtis Creek (CR 300 S) and one on the Iroquois River near Rensselaer (upstream of SR 114) in 1990 (Figure 21). IDEM's results will be compared with results from this study in the Stream Sampling and

Assessment Section. Results of the habitat analysis and macroinvertebrate counts are given in Tables 38 and 39.

TABLE 38. Qualitative Habitat Evaluation Index (QHEI) scores for sites on Curtis Creek and the Iroquois River as assessed by the IDEM Biological Studies Section on October 2 and 3, 1990.

Site	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	Total
Maximum Possible Score	20	20	20	10	12	8	10	**100**
Curtis Creek (CR 300 S)	18	14	14	4	10	6	4	**70**
Iroquois River (SR 114)	20	12	10	8	8	6	4	**68**

Source: Todd Davis, IDEM Biological Studies Section.

TABLE 39. mIBI (macroinvertebrate index of biotic integrity) scores for Curtis Creek and the Iroquois River sampled by the IDEM Biological Studies Section on October 2 and 3, 1990.

	Value	Metric Score
Curtis Creek		
HBI	4.35	6
No. Taxa (families)	12	4
No. Individuals	105	2
% Dominant Taxa	61	2
EPT Index	5	4
EPT Count	78	4
EPT Count/Total Count	74	8
EPT Abun./Chir. Abun	19.5	8
Chironomid Count	4	8
No. Individuals/Square	125	4
mIBI Score		**5.0**
Iroquois River		
HBI	4.33	6
No. Taxa (families)	13	4
No. Individuals	211	4
% Dominant Taxa	34.1	4
EPT Index	5	4
EPT Count	157	6
EPT Count/Total Count	74	8
EPT Abun./Chir. Abun	6.83	6
Chironomid Count	23	4
No. Individuals/Square	211	6
mIBI Score		**5.2**

Source: Todd Davis, IDEM Biological Studies Section.

In general, habitat quality was found to be generally conducive to aquatic life, scoring 70 and 68 of a possible 100 points for Curtis Creek and the Iroquois River, respectively. The mIBI scores for both sites indicate only slight water quality impairment (IDEM, unpublished). Both the

QHEI and the mIBI will be discussed in more detail in the Stream Sampling and Assessment Section.

Fish Community Studies

Introduction

IDEM and the Indiana Department of Natural Resources (IDNR) conducted multiple fish community surveys in the Curtis Creek and Iroquois River Watersheds over the past 20 years (Figure 21). The IDEM Biological Studies Section, in conjunction with the development of the Central Corn Belt Plains Index of Biotic Integrity (IBI), surveyed Curtis Creek and the Iroquois River in 1990. IDEM Biological Studies Section again surveyed the Iroquois River in 1999. The IDNR Division of Fish and Wildlife also assessed the fish community of the Iroquois River in 1989. IDEM surveys are intended to assess biological integrity of a stream system by evaluating the quality of the organisms living in the water. IDNR surveys are generally targeted at evaluating the existing sport fishery and attributes that may affect the fishery.

IDEM Study

As part of their assessment of water quality in Indiana, IDEM uses fish communities as an indicator of stream biological integrity or health. Biological integrity is defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to the best natural habitats within a region" (Karr and Dudley, 1981). To provide a method of determining the biological integrity of an aquatic ecosystem Karr (1981) developed the Index of Biotic Integrity (IBI). Simon (1991) further modified the IBI for evaluation of warmwater stream communities located in the Central Corn Belt Plains Ecoregion of Indiana. The IBI is composed of 12 metrics which are each individually scored based on types and numbers of fish collected in each sample. These individual scores for each of the 12 metrics are then summed to yield an IBI score. An IBI score of 12-22 would indicate very poor biological integrity while the maximum score of 60 would indicate excellent biological integrity.

IDEM conducted two fish community surveys within the Curtis Creek Watershed (Figure 21) and calculated IBI scores for each site in 1991 in conjunction with Simon's development of the Central Corn Belt Plains Ecoregion IBI (Tables 40 and 41). Habitat and the fish community of the Iroquois River was sampled both upstream and downstream of the Curtis Creek confluence in 1999 (Table 40). Table 41 documents the fish captured during the IDEM surveys. IBI values in the Curtis Creek Watershed were directly correlated with distance downstream, meaning that headwater areas had lower biotic integrity and supported more pollution-tolerant individuals than reaches further downstream. Of the two reaches sampled within the Curtis Creek Watershed boundary, one reach fell between the "fair" and "poor" integrity classes, while the second reach fell in the "good" class. The site that fell in between the "fair" and "poor" integrity classes was situated approximately one mile south of current study Site 6, while the IDEM site that was rated as having "good" biological integrity corresponds with Site 4 of this current study (Figure 21). The reach of the Iroquois River upstream of the Curtis Creek confluence possessed an IBI score that fell between the "fair" and "good" integrity classes, while the Iroquois River site located downstream of the Curtis Creek confluence exhibited an IBI score that fell in the "poor" range. These IBI scores can indicate loss of habitat, anthropogenic stress, a disturbed or unbalanced food chain, or other wise unstable environment.

TABLE 40. IBI and integrity class for sites in the Curtis Creek and Iroquois River Watersheds as sampled by the IDEM Biological Studies Section in the summers of 1990 and 1999.

Site (Location)	Date	IBI	Integrity Class
Curtis Creek (Division Rd)	8/14/1990	37	Poor-Fair
Curtis Creek (SR 114)	8/8/1990	52	Good
Iroquois River (CR 400 W)	7/21/1999	46	Fair-Good
Iroquois River (SR 55)	8/25/1999	34	Poor

Source: Stacey Sobat, IDEM Biological Studies Section.

TABLE 41. Fish captured during the 1990 IDEM survey of Curtis Creek and the 1999 IDEM survey of the Iroquois River.

Common Name	Scientific Name	Curtis Creek (Division Rd.)	Curtis Creek (SR 114)	Iroquois River (CR 400 W)	Iroquois River (SR 55)
Banded darter	*Etheostoma zonale*	X	X	X	
Bigmouth buffalo	*Ictiobus cyprinellus*				X
Black crappie	*Pomoxis nigromaculatus*				X
Black redhorse	*Moxostoma duquesnei*			X	
Blackside darter	*Percina maculate*		X	X	X
Bluegill	*Lepomis macrochirus*			X	X
Bluntnose minnow	*Pimephales notatus*		X	X	
Central mudminnow	*Umbra limi*	X			
Channel catfish	*Ictalurus punctatus*		X	X	
Common carp	*Cyprinus carpio*	X		X	X
Creek chub	*Semotilus atromaculatus*		X		
Golden redhorse	*Moxostomaerythrurum*			X	X
Grass pickerel	*Esox americanus*	X		X	
Green sunfish	*Lepomis cyanellus*	X	X	X	X
Hornyhead chub	*Nocomis biguttatus*		X		
Johnny darter	*Etheostoma nigrum*	X	X	X	
Lake chubsucker	*Erimyzon sucetta*	X			
Largemouth bass	*Micropterus salmoides*	X		X	X
Largescale stoneroller	*Campostoma oligolepis*		X		
Logperch	*Percina caprodes*			X	
Longear sunfish	*Lepomis megalotis*			X	X
Northern hogsucker	*Hypentelium nigricans*		X		
Northern pike	*Esox lucius*		X		
Orangespotted sunfish	*Lepomis humilis*				X
Pirate perch	*Aphredoderus sayanus*	X			
Pumpkinseed	*Lepomis gibbosus*	X			
Rock bass	*Ambloplites rupestris*		X	X	X
Sand shiner	*Notropis ludibundus*		X		
Shorthead redhorse	*Moxostoma macrolepidotum*		X		
Silverjaw minnow	*Ericymba buccata*		X		
Slenderhead darter	*Percina squamata*			X	X
Spotfin shiner	*Cyprinella spiloptera*		X	X	

Common Name	Scientific Name	Curtis Creek (Division Rd.)	Curtis Creek (SR 114)	Iroquois River (CR 400 W)	Iroquois River (SR 55)
Spotted bass	*Micropterus punctulatus*				X
Spotted sucker	*Minytrema melanops*				X
Striped shiner	*Luxilus chrysocephalus*		X	X	X
Stonecat	*Noturus flavus*			X	
Tadpole madtom	*Noturus gyrinus*	X			
Yellow bullhead	*Ameiurus natalis*	X		X	X

Source: Stacey Sobat, IDEM Biological Studies Section.

Fish community data collected in 1990 was utilized to develop the IBI for the Central Corn Belt Plain. During species collection and analysis Simon noted that in most cases the biotic integrity of the Iroquois River Basin did not vary much with basin size (1991). Generally, low IBI scores could be attributed to poor habitat conditions such as low flows, the accumulated soft substrate, reduced riffle/pool habitat, and dredged streambeds (Simon, 1991). While Simon noted that all of the streams in the Iroquois River basin are degraded and have suffered from the impacts of human land alterations, he calls Curtis Creek an "exceptional stream in the Iroquois River Basin" due to its high (relative to other streams in the Iroquois River basin) IBI score.

In general, habitat quality was found to be "poor" or inconducive to supporting aquatic life, scoring 47 and 42 of a possible 100 points for the upstream and downstream portions of the Iroquois River, respectively (Table 42). The QHEI will be discussed in more detail in the Stream Sampling and Assessment Section.

TABLE 42. Qualitative Habitat Evaluation Index (QHEI) scores for sites on the Iroquois River as assessed by the IDEM Biological Studies Section on July 21 and August 25, 1999.

Site	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	Total
Maximum Possible Score	20	20	20	10	12	8	10	**100**
Iroquois River (CR 400 W)	13	8	7	5	8	0	6	**47**
Iroquois River (SR 55)	1	13	8	8	8	0	4	**42**

Source: Stacey Sobat, IDEM Biological Studies Section.

IDNR Study

In June and July of 1989, the IDNR sampled three sites on the Iroquois River, two upstream and one downstream of the confluence with Curtis Creek (Figure 21). The IDNR collected at total of 19 species representing six families during the study (Table 43). Quillback, carp, shorthead redhorse, bluntnose minnow, and bigmouth buffalo accounted for nearly 90% of the community. Carp, suckers, and buffalo comprised 98% of the population by weight. Game fish accounted for only 5% and 2% of the sample population by number and weight, respectively. Turbid water, a deep channel, and extremely steep banks limit the fishing potential of the Iroquois River. Based on the survey results, IDNR biologists believed that the reduction of soil runoff and the addition of habitat improvement structures would improve water quality and game fish populations in the Iroquois River (Robertson, 1990).

TABLE 43. Fish captured during the 1989 IDNR Survey of the Iroquois River. Sites are listed from the location furthest upstream (SR 114) to that furthest downstream (100 W).

Common Name	Scientific Name	SR 114	I-65	CR 100W
Bigmouth buffalo	*Ictiobus cyprinellus*	X		
Bluntnose minnow	*Pimephales notatus*	X		
Channel catfish	*Ictalurus punctatus*		X	X
Common carp	*Cyprinus carpio*	X	X	X
Common shiner	*Luxilus cornutus*			X
Gizzard shad	*Dorosoma cepedianum*		X	
Golden redhorse	*Moxostoma erythrurum*	X	X	X
Ironcolor shiner	*Notropis chalybaeus*		X	
Largemouth bass	*Micropterus salmoides*		X	
Longear sunfish	*Lepomis megalotis*			X
Northern hogsucker	*Hypentelium nigricans*	X	X	
Northern pike	*Esox lucius*		X	X
Quillback	*Carpoides cyprinus*	X	X	X
River carpsucker	*Carpiodes carpio*			X
Smallmouth bass	*Micropterus dolomieu*		X	X
Rock bass	*Ambloplites rupestris*	X	X	
Shorthead redhorse	*Moxostoma macrolepidotum*	X	X	X
Silver redhorse	*Moxostoma anisurum*			X
Smallmouth buffalo	*Ictiobus bubalus*	X		X

Natural Communities and Endangered, Threatened and Rare Species

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened and rare species, high quality natural communities, and natural areas in Indiana. The database was developed to assist in documenting the presence of special species and significant natural areas and to serve as a tool for setting management priorities in areas where special species or habitats exist. The database relies on observations from individuals rather than systematic field surveys by the Indiana Department of Natural Resources (IDNR). Because of this, it does not document every occurrence of special species or habitat. At the same time, the listing of a species or natural area does not guarantee that the listed species is present or that the listed area is in pristine condition. To assist users, the database includes the date that the species or special habitat was last observed and reported in a specific location.

Results from the database search for the Curtis Creek Watershed are presented in Appendix 4. (For additional reference, a listing of endangered, threatened, and rare species documented in Jasper and Newton Counties is included in Appendix 5.) According to the database, the study watershed supports one high quality community type within the study area: the dry sand savanna. Dry sand savanna was noted in two locations along the northeastern border of the Curtis Creek Watershed. The database also lists sightings of three state endangered species, the upland sandpiper (*Bartramia longicauda*, 1997), the American badger (*Taxidea taxus*, 1988), and the Blanding's turtle (*Emydoidea blandingii*, 1946). State threatened and rare plants, including western silvery aster (*Aster sericeus*, 1981), northeastern smartweed (*Polygonum hydropiperoides*, 1984), and prairie fame flower (*Talinum rugospermum*, 1988), the plains pocket gopher (*Geomys bursarius*, 1988), and the western ribbon snake (*Thamnophis proximus*, no date) are species associated with high quality natural areas and have been documented in areas between Curtis Creek and the Interstate 65 corridor (Township 30 North, Ranges 7 and 8 West).

WATERSHED STUDY

The watershed study is composed of two main components: the watershed investigation and the stream assessment. The watershed investigation entailed both an aerial tour and a windshield survey of the Curtis Creek Watershed. The stream sampling and assessment involved: 1) stream water quality sampling at ten sites during base flow and during stormwater runoff; 2) a Qualitative Habitat Evaluation Index (QHEI) calculation for all ten sites; and 3) a macroinvertebrate Index of Biotic Integrity (mIBI) calculation for each stream sampling site.

Watershed Investigation

Introduction

Identifying areas of concern and selecting sites for future management are the goals of the visual watershed inspection. The study area watershed was toured by airplane in April 2002 and a windshield survey was conducted in November 2002 after most crops were removed. The observations made during these two surveys are presented below. Figure 25 offers a summary of observations made during the both the aerial tour and the windshield survey.

Aerial Tour

The aerial tour consisted of flying over the watershed at fairly low altitudes in order to photograph high priority and environmentally sensitive areas. Areas of concern with corresponding aerial photos are discussed by subwatershed, and their locations are mapped on Figure 25. Photos of unique problems are included in the discussion of each subwatershed.

Mouth of Curtis Creek Subwatershed. Five potential areas of concern were documented during the aerial tour of the Mouth of Curtis Creek Subwatershed (Table 44; Sites A9-13; Figure 25). Land near the confluence of Curtis Creek and Yeoman Ditch appeared to have been overgrazed. Livestock should be excluded from the area near the stream to preserve banks and prevent water contamination (Figure 26). Grassed waterways are also recommended to protect against further rill and gully erosion at Sites A10, A11, and A13.

TABLE 44. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Mouth of Curtis Creek Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A9	Land appears to be heavily grazed; land is farmed to stream’s edge	Livestock fencing; allow natural riparian vegetation growth; filter strips
A10	Rill and gully erosion is evident	Grassed waterway installation
A11	Rill and gully erosion is evident	Grassed waterway installation
A12	Land is farmed to stream’s edge	Filter strips
A13	Rill and gully erosion is evident	Grassed waterway installation

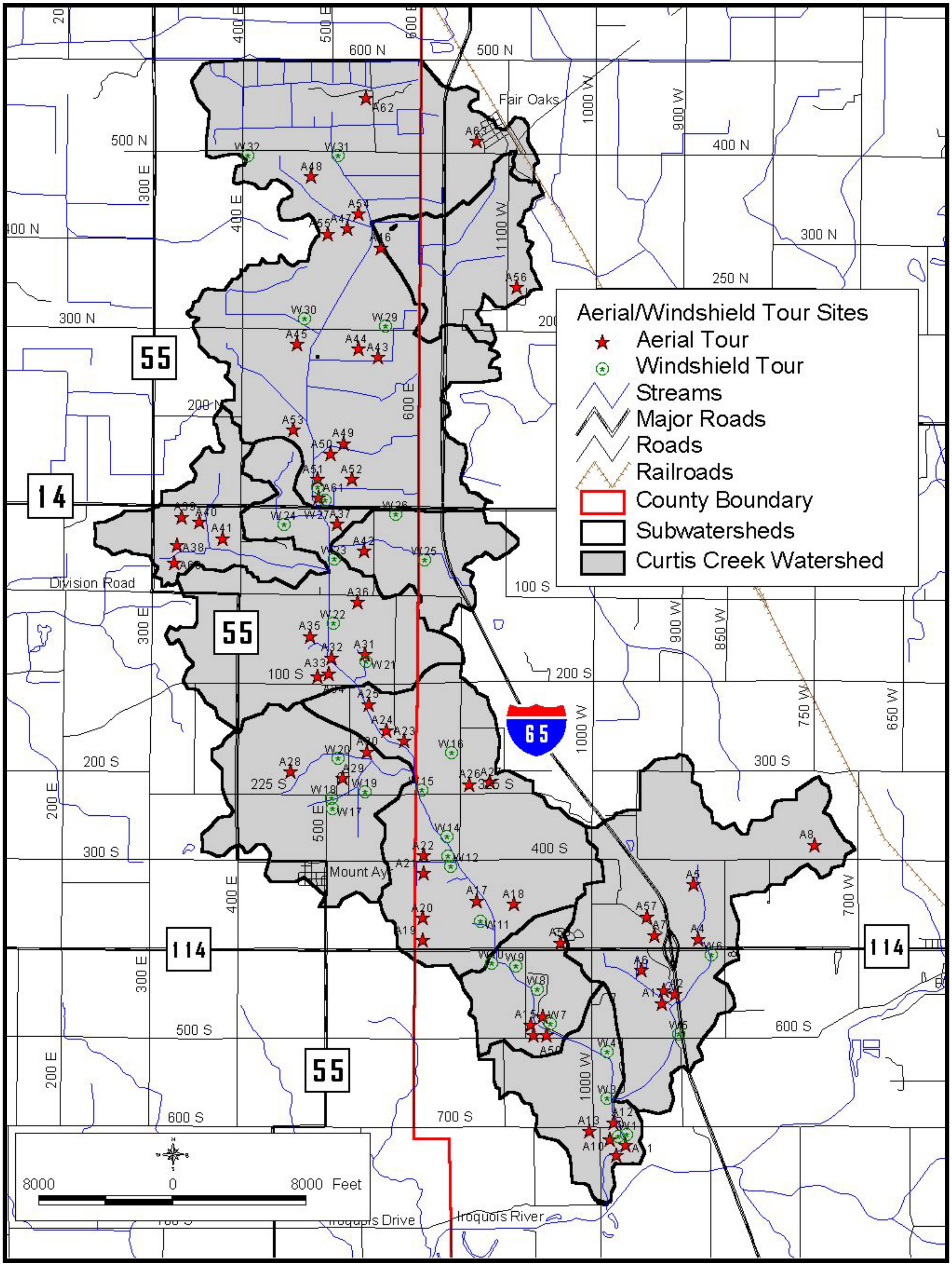


FIGURE 25. Aerial tour and windshield survey location map.

FIGURE 26. Site A9 showing area of heavy grazing in the Mouth of Curtis Creek Subwatershed.

Yeoman Ditch Subwatershed. Table 45 contains data relevant to 8 sites in the Yeoman Ditch Subwatershed where land management actions could improve water quality (Sites A1-8; Figure 25). Remnant wetlands and hydric soils were evident in Sites A2, A3, A7, and A8 (Figure 27) where wetland restoration could be possible. Restored wetlands increase water storage capacity in the watershed, thereby reducing runoff volumes during storm events. Large runoff events can erode soils from the landscape. Large volumes of water that reach stream channels can erode the channel bed and banks as well. Wetlands also offer mechanical and biological filtration of water that effectively removes sediment, pathogens, nutrients, and other chemicals from runoff. An additional area of concern in the Yeoman Ditch Subwatershed is the development around the intersection of Interstate 65 and State Road 114 (Figure 28). A group of approximately 15 restaurants, hotels, and gas stations crowd this intersection. Three of these, McDonald's Restaurant, Trail Tree Truck Plaza, and Grandma's Home Cookin' Restaurant are permitted to discharge wastewater to Yeoman Ditch tributaries.

TABLE 45. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Yeoman Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A1	Land is farmed to stream's edge	Filter strips
A2	NA	Wetland restoration is possible
A3	Land is farmed to stream's edge	Filter strips
A4	Rill and gully erosion is evident; land is farmed to stream's edge	Grassed waterway installation
A5	Land is farmed to stream's edge	Filter strips
A6	Land is farmed to stream's edge	Filter strips
A7	NA	Wetland restoration is possible
A8	NA	Wetland restoration is possible

NA=Not Applicable

FIGURE 27. Site A3 showing a potential wetland restoration site in the Yeoman Ditch Subwatershed.

FIGURE 28. Site A55 showing a portion of the commercial development at the intersection of SR 114 and I-65.

Golf Course Subwatershed. Much of the Golf Course Subwatershed was not captured in photos taken during the aerial tour. For this reason, it received more attention during the driving tour and will be discussed in the Windshield Tour Section. Three areas that might benefit from management applications for the Golf Course Subwatershed were identified during the aerial tour (Table 46; Sites A14 and 15; Figure 25). Mowing to the stream edge and sloughing banks were noted along the length of the golf course (Figure 29). Two additional areas located during the aerial tour, the Curtis Creek Golf Course and a developing subdivision along State Road 114, may be impairing water quality in Curtis Creek.

TABLE 46. List of locations where the application of best management practices would improve water Golf Course Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A14	Land is mowed to stream's edge	Filter strips
A15	Land is farmed to stream's edge	Filter strips
A16	Banks are eroding	Allow natural riparian vegetation growth

FIGURE 29. Site A56 showing the Curtis Creek Golf Course.

State Road 114 Subwatershed. Table 47 contains data relevant to 11 sites in the State Road 114 Subwatershed where land management actions could improve water quality (Sites A17-27; Figure 25). Multiple potential wetland restoration sites were identified during the aerial tour. Photos taken in the State Road 114 Subwatershed document a practice that is typical in the study watershed: farming at or very near the stream's edge as shown in Figure 30. The eastern stream bank (right side of photo) is an ideal candidate for filter strip installation.

TABLE 47. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the State Road 114 Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A17	Land is farmed to stream's edge	Filter strips
A18	NA	Wetland restoration is possible
A19	Rill and gully erosion is evident	Grassed waterway installation
A20	NA	Wetland restoration is possible
A21	NA	Wetland restoration is possible
A22	NA	Wetland restoration is possible
A23	Rill and gully erosion is evident	Grassed waterway installation
A24	NA	Wetland restoration is possible
A25	Banks are eroding	Allow natural riparian vegetation growth
A26	Rill and gully erosion is evident	Grassed waterway installation
A27	NA	Wetland restoration is possible

NA=Not Applicable

FIGURE 30. Site A23 showing representative need for filter strips (east stream bank) in the State Road 114 Subwatershed.

Long Ditch Subwatershed. Most photos taken of the Long Ditch Subwatershed were not detailed enough to discern individual problems. For this reason, additional time was spent in the Long Ditch area during the windshield watershed tour. Long Ditch will be discussed in more detail in the Windshield Tour Section. Three areas of concern were identified from photographs of areas along the headwaters of Long Ditch (Table 48; Sites A28-A30; Figure 25).

TABLE 48. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Long Ditch Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A28	Land is grazed to stream's edge	Filter strips
A29	Rill and gully erosion is evident	Grassed waterway installation
A30	Land is grazed to stream's edge	Filter strips

County Road 100 South Subwatershed. Seven areas that would benefit from management practices were documented during the aerial tour of the County Road 100 South Subwatershed (Table 49; Sites A31-A37; Figure 25). Riparian revegetation and filter strip or grassed waterway construction would help to slow erosion at six of the sites. Figure 31 shows gully and rill erosion indicative of the need for grassed waterway installation. Site A37 (Figure 32) also offers potential for a wetland restoration project which would expand water-holding capacity in the watershed and help slow erosion processes downstream. (This wetland lies on the Kosta Ditch-County Road 100 South Subwatershed boundary.)

TABLE 49. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the County Road 100 South Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A31	Land is farmed to stream's edge	Filter strip
A32	Banks are eroding	Allow natural riparian vegetation growth
A33	Rill and gully erosion is evident	Grassed waterway installation
A34	Rill and gully erosion is evident	Grassed waterway installation
A35	Land is farmed to stream's edge; banks are eroding	Allow natural riparian vegetation growth; filter strips
A36	Rill and gully erosion is evident	Grassed waterway installation
A37	NA	Wetland restoration is possible

NA=Not Applicable

FIGURE 31. Site A35 showing representative need for grassed waterway installation.

FIGURE 32. Site A37 showing potential wetland restoration site.

Elijah Ditch Subwatershed. Aerial photo documentation of the Elijah Ditch Subwatershed only revealed four locations in the headwaters where land management actions could improve water quality (Table 50; Sites A38 to A42; Figure 25). Photos also identified one potential pollution area: a hog farm containing approximately 2,500 head of hogs located adjacent to an unnamed tributary to Long Ditch (Figure 33). Photos of the downstream reach of Elijah Ditch were not detailed enough to discern individual problems. For this reason, additional time was spent in the Elijah Ditch area during the windshield survey. The area will be discussed in more detail in the Windshield Survey Section.

TABLE 50. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Elijah Ditch Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A38	Land is farmed to stream's edge	Filter strip
A39	NA	Wetland restoration is possible
A41	Banks are eroding; land is farmed to stream's edge	Allow natural riparian vegetation growth; filter strips
A42	Land is farmed to stream's edge	Filter strips

NA=Not Applicable

FIGURE 33. Site A60 showing a hog farm adjacent to a tributary to Elijah Ditch.

Kosta Ditch Subwatershed. Photos taken of the Kosta Ditch Subwatershed were not detailed enough to discern individual problems. For this reason, additional time was spent in the Kosta Ditch area during the windshield watershed tour. Kosta Ditch will be discussed in more detail in the Windshield Tour Section.

Headwaters Subwatershed. The aerial tour revealed 10 sites of concern in the Headwaters Subwatershed (and an additional site on the subwatershed boundary between the Headwaters and

Fair Oaks Subwatersheds). Installation of BMPs such as bank stabilization, filter strip or grassed waterway construction, and wetland restoration in the Headwaters Subwatershed would benefit the entire Curtis Creek Watershed. Table 51 lists the location, concern, and potential land management practice that would address the concern for each of the ten sites in the Headwaters subwatershed (Table 49; Sites A43-A54; Figure 25). Additionally, four dairy barns in both Newton and Jasper Counties and a construction project at the future location of a milk-truck washing facility adjacent to Curtis Creek were located (Sites A55, A56, A61, and A62; Figure 34 and 35).

TABLE 51. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Headwaters of Curtis Creek Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A43	Land is farmed to stream's edge	Filter strips
A44	NA	Wetland restoration is possible
A45	Banks are eroding	Stream bank stabilization
A46	Rill and gully erosion is evident	Grassed waterway installation
A47	Rill and gully erosion is evident	Grassed waterway installation
A48	NA	Wetland restoration is possible
A49	Land is farmed to stream's edge	Filter strips
A50	NA	Wetland restoration is possible
A51	NA	Wetland restoration is possible
A53	NA	Wetland restoration is possible
A54	Irrigation at stream edge	Back irrigation away from stream's edge

NA=Not Applicable

FIGURE 34. Site A61 showing construction of a milk-truck washing facility in the Headwaters Subwatershed. Once complete, the facility will be utilized to rinse milk trucks with chlorinated water, which will then be held in wastewater ponds for primary treatment.

FIGURE 35. Site A62 showing one of the Fair Oaks Dairy barns.

Fair Oaks Subwatershed. As was the case with photos of the Kosta Ditch Subwatershed, aerial photos of the Fair Oaks Subwatershed did not offer enough detail for problem or resource analysis. The Fair Oaks Subwatershed will be discussed in more detail in the Windshield Tour Section.

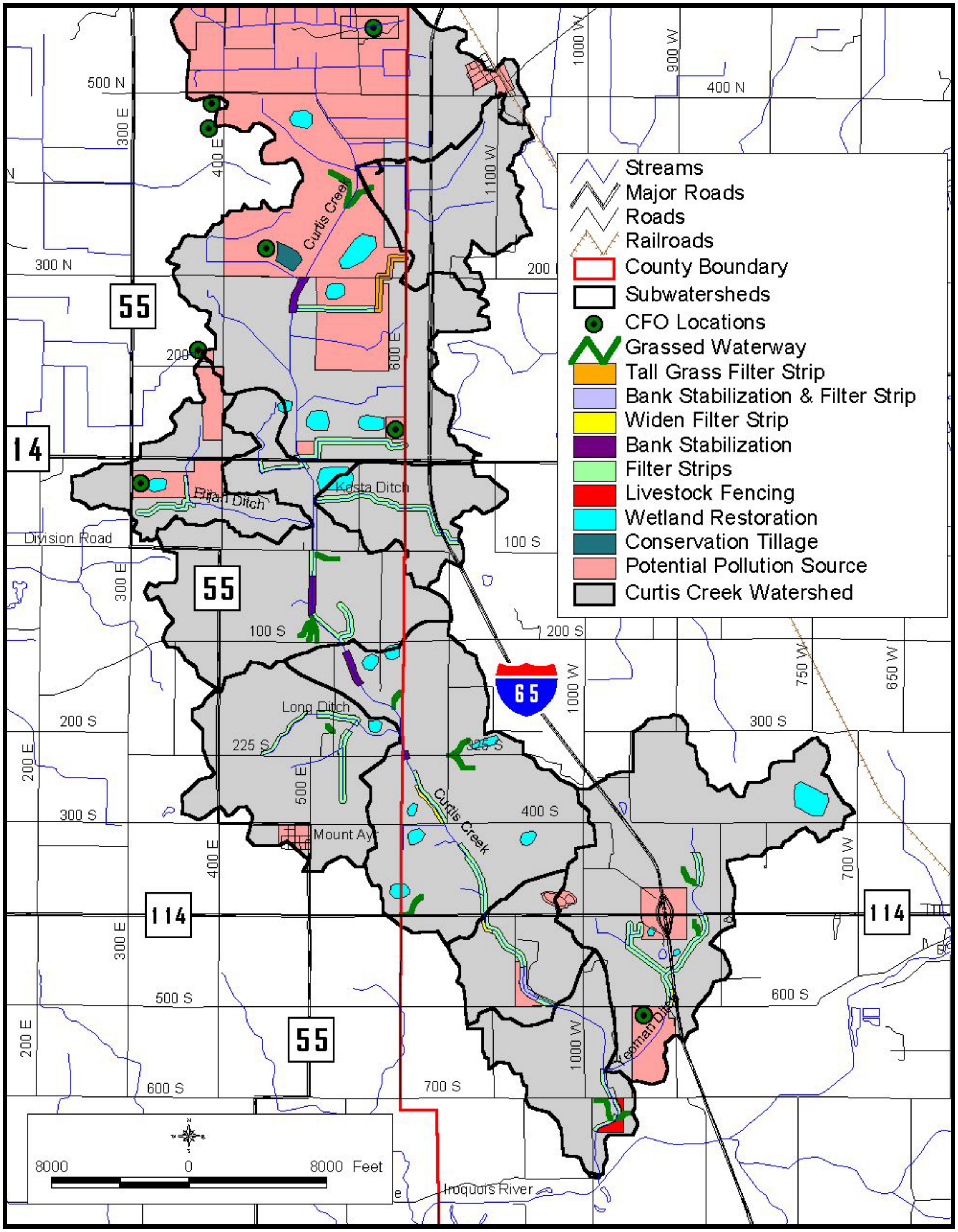


FIGURE 36. Management recommendations and locations of potential pollution sources.

Windshield Tour

Introduction

The windshield survey was conducted November 1, 2002 and entailed driving the watershed and assessing the streams where they crossed or were adjacent to roads. Carla Orlandi and Larry Strole of the Newton County SWCD, Jeff LaCosse of the Newton County Surveyor's Office, and Jennifer Bratthauer of the IDNR participated in the tour. Particular areas of concern were examined more closely by stopping and walking areas within public right-of-way.

Observations made during the windshield tour fall into two different classes: observations relating to sites having potential for best management practice implementation (like fields bordering streams and needing filter strips) and observations relating to sites or operations which may contribute point or non-point source pollution to the streams (like the McDonald's WWTP or the Fair Oaks Confined Feeding Operation). These two classes are discussed below and their locations appear in Figures 25 and 36. Potential Pollution Sources are displayed in pink on the Management Recommendations map (Figure 36). The three NPDES permitted facilities are contained within the square located at the intersection of State Road 114 and Interstate 65. Location of dairy and hog barns are indicated by green points; pink areas surrounding and/or adjacent to the barns are locations where these facilities apply manure in accordance with IDEM regulations (IDEM File Logs). Additional potential pollution sources mapped in Figure 36 include the towns of Fair Oaks and Mount Ayr, the Curtis Creek Golf Course located at the intersection of County Road 600 South and 1000 West, and an expanding subdivision immediately north of State Road 114.

Sites for Potential Management Practice Implementation

Most observations made during the windshield tour relate to needs for best management practice implementation in the study areas. Table 52 lists all sites where BMPs implementation or installation could benefit water quality. Three additional locations are also included in Table 50. These include two grassed waterways and one filter strip that were identified as good examples of the best management practice during the windshield tour. Site locations are displayed in Figure 25 and photos appear in Figure 37-40.

TABLE 52. List of sites and corresponding BMPs compiled during the windshield survey of the Curtis Creek Watershed.

Subwatershed	Site	Recommended BMP
Mouth of Curtis Creek	W1	Fence livestock from stream
Mouth of Curtis Creek	W2	Filter strip
Mouth of Curtis Creek	W3	Filter strip
Mouth of Curtis Creek	W4	Filter strip
Yeoman Ditch	W5	Enlarge filter strip width
Yeoman Ditch	W6	Grassed waterway construction
Golf Course	W7	Filter strip; revegetate exposed areas of stream bank (Figure 37)
Golf Course	W8	Increase riparian width (Figure 38)
Golf Course	W9	Filter strip

Subwatershed	Site	Recommended BMP
Golf Course	W10	Enlarge existing riparian buffer area
SR 114	W11	NA; good filter strip
SR 114	W11	Filter strip
SR 114	W12	Enlarge filter strip width
SR 114	W13	Filter strip
SR 114	W15	Bank stabilization
SR 114	W16	Grassed waterway construction
Long Ditch	W17	NA; good grassed waterway
Long Ditch	W18	NA; good grassed waterway
Long Ditch	W19	Filter strip
Long Ditch	W20	Filter strip
CR 100 South	W21	Filter strip
CR 100 South	W22	Filter strip
CR 100 South	W23	Filter strip; bank stabilization
CR 100 South	W24	Filter strip
Kosta Ditch	W25	Filter strip
Kosta Ditch	W26	Institute erosion control methods; revegetate construction site
Headwaters of Curtis Creek	W27	Institute erosion control methods; revegetate construction site (Figure 39)
Headwaters of Curtis Creek	W28	Establish windbreaks to reduce areal nutrient loss*
Headwaters of Curtis Creek	W29	Tall grass filter strip
Headwaters of Curtis Creek	W30	Enroll steep hill in CRP; at minimum this ground should be conservation-tilled
Headwaters of Curtis Creek	W31	Incorporate wetland filtering system into current manure management plan (Figure 40)
Headwaters of Curtis Creek	W32	Institute erosion control methods; revegetate construction site

*Windbreaks are suggested as a method to reduce areal transport or nutrients and odor associated with the dairies throughout the Headwaters Subwatershed. Exact locations for windbreak installation are not mapped on the recommendations map due to lack of accessibility during the windshield tour of the watershed. It is suggested that the Newton County SWCD and NRCS work with Fair Oaks Dairy to determine locations where windbreak planting would be conducive.

FIGURE 37. Site W7 taken during the windshield survey showing the need for filter strips and bank revegetation in the Golf Course Subwatershed.

FIGURE 38. Site W8 taken during the windshield survey showing unstable banks and the need for increased riparian vegetation width in the Golf Course Subwatershed.

FIGURE 39. Site W27 taken during the windshield survey showing unstable banks and the need for erosion control in the Headwaters Subwatershed.

FIGURE 40. Site W31 taken during the windshield survey showing a sediment plume from a surface drainage tile in the Headwaters Subwatershed.

Potential Contributors of Point or Non-Point Source Pollution

Some observations made during the windshield survey revealed operations that may contribute to water pollution in more direct ways. Because no data was collected during this study to test effluent or runoff from any of the following facilities or operations, it was not possible to determine if or to what extent their activities may contribute to water pollution. The current study documented their existence and location and recognized their potential to contribute to either point or non-point source pollution.

Yeoman Ditch Subwatershed

Several point and non-point source contributors were noted during the Yeoman Ditch Subwatershed tour: a hog farm, three Wastewater Treatment Plants (WWTP), and Interstate 65 (I-65). Korniak Farms operates a confined feeding operation at the intersection of County Roads 900 West and 600 South. The farm is permitted to house approximately 1,800 hogs and spread nearly 143,500 cubic feet of manure annually. A proper manure/waste management plan would help to minimize impacts that the hog farm may have on water quality. The McDonald's WWTP treats effluent from restaurant restrooms and restaurant wash water. Grandma's Home Cookin' WWTP treats effluent from Truck Stop restrooms, restaurant, and showers, Cooper's Truck Lube Plus restrooms, Burger King restrooms and wash water, and Fireworks Factory Outlet restrooms. The Trail Tree WWTP treats effluent from the Trail Tree Inn Plaza including the restaurant and hotel and the Mid-Continent Inn. Permits for the three facilities contain total Kjeldahl nitrogen, total suspended solid, biological oxygen demand (BOD), and pathogen (*E. coli*) loading limits, but do not require testing for phosphorus or calculation of phosphorus loading to the stream. In sum these WWTPs add nutrients and bacteria to the Curtis Creek Watershed streams. Additionally, I-65 runs through the subwatershed, crossing Yeoman Ditch north of County Road 600 South. The interstate could be a significant source of metals or hydrocarbons from fuels, oils, and the combustion of fuels and oils. Additional growth around the I-65/SR 114 interchange will only increase the amount of impervious surfaces within the subwatershed. This increase coupled with the lack of existing infrastructure for stormwater treatment could negatively impact water quality in Yeoman Ditch.

Golf Course Subwatershed

The Curtis Creek Golf Course is located at the intersection of County Roads 600 South and 1075 West in the Golf Course Subwatershed. Curtis Creek runs through the center of the golf course from County Road 1075 West to County Road 600 South. Narrow riparian buffers coupled with potentially high nutrient application rates could impair water quality. Additionally, large numbers of golfers utilizing septic facilities at the location may also have implications for water quality.

Long Ditch Subwatershed

The Long Ditch Subwatershed contains the town of Mount Ayr. Wastewater from Mount Ayr drains to Long Ditch via the Stucker Drain. Individual reported a suspected septic failure or straight pipe discharge to Stucker Drain during the completion of the study. (As discussed in the Soils Section, septic discharge can contribute high levels of nutrients, organic solids, and pathogens to surface waters. The Newton County Health Department has been informed of the issue and should implement measures to correct this issue.)

Elijah Ditch Subwatershed

The Elijah Ditch Subwatershed contains a hog farm operated by Cambalot Swine Breeders. The Cambalot Swine Breeders operate a hog farm near the headwaters of Elijah Ditch. The farm is permitted to house 5,225 hogs and apply up to 442,600 cubic feet of manure annually. A proper manure/waste management plan and the usage of Best Management Practices would help to minimize impacts that the hog farm may have on water quality.

Headwaters Subwatershed

One dairy and the town of Fair Oaks are located in the Headwaters Subwatershed. Fair Oaks Dairy maintains four barns which house a total of 12,000 dairy cattle. (Fair Oaks Dairy is regulated to maintain six barns housing 18,000 head of dairy cattle. The final two barns have not yet been completed.) The dairy is permitted to produce over 8 million cubic feet of manure annually which is spread on agricultural fields located throughout and adjacent to the Headwaters and Fair Oaks Subwatersheds. The dairy has recently been approved for the construction of two additional barns each of which will house 3,000 dairy cattle. Construction of one of these new facilities was noted during the watershed tour. Two additional dairy facilities, a milk-truck washing operation and a small-scale cheese manufacturing plant, were also under construction during the watershed tour. Because it is often difficult to prevent soil erosion during construction, it is possible that the construction projects resulted in some sediment and sediment-attached nutrient loading to Curtis Creek. Once constructed these facilities have the potential to contribute large volumes of organic solids to Curtis Creek. Proper maintenance and wastewater treatment should occur at both facilities to prevent nutrient, pathogen, or organic solids loading to Curtis Creek. Fair Oaks Dairy reports that plans include expansion to housing 24,000 dairy cattle and full time operation of the Fair Oaks Dairy Adventure which will include tours, educational opportunities, and the previously discussed cheese factory (More information can be obtained from the Fair Oaks Dairy website at www.fairoaksdairyadventure.com.) Additionally, a new I-65 interchange has been approved at SR 14. The growth of restaurants, hotels, and gas stations around the new interchange could increase the amount of impervious surfaces within the subwatershed and introduce other potential pollutant sources.

Permitted Point Source Discharge Compliance Report Discussion

Three separate facilities currently hold permits from the state to discharge specified loads of certain pollutants into streams within the study watershed area. Permitted facilities are required to monitor their discharge and submit compliance reports to the state on a monthly basis. A facility that exceeds its permitted discharge level is in violation and must correct the problem in a timely manner.

McDonald's Restaurant Wastewater Treatment Plant (WWTP) treats wastewater from the restroom and restaurant wash water and currently holds a permit to discharge treated water into Pancost Ditch, a tributary to Yeoman Ditch (Figure 36). The restaurant is located at 8834 W. State Road 114. Discharge water is monitored for dissolved oxygen (DO), pH, total suspended solids (TSS), ammonia-nitrogen (NH_3-N), nitrate-nitrogen, oil and grease, flow, chlorine and carbonaceous biological oxygen demand (C-BOD). Table 53 contains the effluent limits required by McDonald's National Pollution Discharge Elimination System (NPDES) permit.

TABLE 53. Effluent limitations and monitoring requirements for the McDonald's wastewater treatment plant.

Parameter	Monthly Average Load	Monthly Average Concentration
C-BOD	0.6 lb/d; 0.9 lb/d (summer); 1.5 lb/d (winter)	10 mg/l; 15 mg/l (summer); 25 mg/l (winter)
TSS	0.6 lb/d; 1.1 lb/d (summer); 1.8 lb/d (winter)	10 mg/l; 18 mg/l (summer); 30 mg/l (winter)
NH_3-N	0.06 lb/d (summer); 0.09 lb/d (winter)	1.1 mg/l (summer); 1.6 mg/l (winter)
Oil and Grease	--	10 mg/l
Parameter	**Daily Minimum**	**Daily Maximum**
DO	6.0 mg/l (summer); 5.0 mg/l (winter)	--
pH	6	9
Residual Chlorine	--	0.02 mg/l

Source: McDonald's NPDES Permit #IN0063933.

McDonald's Restaurant has been cited multiple times for being in non-compliance with Indiana Code. An inspection conducted in 1996 found that the WWTP met all NPDES permit requirements except for dissolved oxygen (Paul Sechrist, IDEM inspector, unpublished). The 1996 inspection form included the notation that plans for the McDonald's WWTP to connect with the Rensselaer sewage treatment plant "fell through"; this development required McDonald's to upgrade their facility. Inspections conducted in 1997 and 1998 reported that little to no improvements had been completed on the facility. The inspector noted dead spots (areas where anaerobic decomposition could not occur due to low bacterial populations) in the aeration tank, two oil and grease violations from when employees poured waste grease into the WWTP line, and 82 dissolved oxygen violations. In 1998 and 1999, the McDonald's WWTP violated of their dissolved oxygen effluent requirement one or more days of every month (Table 54). Additional problems included: septic solids discharge to Pancost Ditch, clogged aerators, bacteriologically unhealthy treatment ponds (mixed liquor), lack of significant mixing, and excessive trash and debris (R. D. Alley, IDEM inspector, unpublished). The McDonald's WWTP continues to have problems complying with their dissolved oxygen effluent limits (Table 54). When in violation, the plant reported minimum dissolved oxygen concentrations ranging from <3.0-5.6 mg/l. McDonald's was in violation nearly 100% of the months in which samples were collected. Plans to update this wastewater treatment plant in order to bring it back into compliance were being discussed during the completion of this study (Carla Anderson, Jasper County Soil and Water Conservation District, personal communication).

TABLE 54. Number of times and percentage of time McDonald's was in violation of its permit for chemical discharge from March 1997-January 2002.*

Parameter	Number of Times Violation Occurred	% of Time Plant was in Violation
C-BOD	2	4%
TSS	9	19%
NH_3-N	0	--
Oil and Grease	3	6%
DO	44	94%
pH	0	--

Source: EPA's Envirofacts Warehouse database; R.D. Alley and P. Sechrist, IDEM permit files.
*Effluent information was reported for 47 of the 70 months during this time period. Therefore, the percent of time in violation was calculated by dividing the total number of violations by the 47 months of reported data.

Grandma's Home Cookin' located at 9378 W. State Road 114 also currently holds a permit to discharge by-products of waste treatment to Pancost Ditch (Figure 36). This treatment facility handles waste from Grandma's Home Cookin' Truck Stop restroom, restaurant, and showers; Cooper's Truck Lube Plus restrooms; Burger King restrooms and wash water; and Fireworks Factory Outlet restrooms. Treatment effluent must meet certain standards for: DO, pH, TSS, NH_3-N, chlorine, flow, and C-BOD. Table 55 contains effluent limits for the Grandma's wastewater treatment plant (WWTP). Grandma's Home Cookin' was in violation of its discharge limits for only one month when samples were taken (Table 56). The only water quality violation occurred during the winter and resulted in nearly ten times the permitted ammonia-nitrogen concentration. Two additional operating violations occurred when Burger King employees dumped cooking oil down the drain on separate occasions in June and August of 1997.

TABLE 55. Effluent limitations and monitoring requirements for Grandma's Home Cookin' wastewater treatment plant.

Parameter	Monthly Average Load	Monthly Average Concentration
C-BOD	3.6 lb/d (summer); 6.0 lb/d (winter)	15 mg/l (summer); 25 mg/l (winter)
TSS	4.3 lb/d (summer); 7.2 lb/d (winter)	18 mg/l (summer); 30 mg/l (winter)
NH_3-N	0.3 lb/d (summer); 0.4 lb/d (winter)	1.1 mg/l (summer); 1.6 mg/l (winter)
Parameter	**Daily Minimum**	**Daily Maximum**
DO	6.0 mg/l (summer); 5.0 mg/l (winter)	--
pH	6	9
Residual Chlorine	--	0.02 mg/l

Source: Grandma's Home Cookin' NPDES Permit #IN0053422.

TABLE 56. Number of times and percentage of time the Grandma's Home Cookin' wastewater treatment plant was in violation of its permit for chemical discharge from January 1997-July 2001.

Parameter	Number of Times Violation Occurred	% of Time Plant was in Violation
C-BOD	0	--
TSS	0	--
NH_3-N	1	7%
DO	0	--
pH	0	--
Oil and Grease	2	14%

Source: EPA's Envirofacts Warehouse database.

Trail Tree Truck Stop located at 9435 W. State Road 114 also currently holds a permit to discharge by-products of municipal waste treatment to an unnamed tributary to Yeoman Ditch (Figure 36). This treatment facility handles waste from the Trail Tree Inn Plaza, including the restaurant and hotel, and the Mid-Continent Inn. Treatment effluent must meet certain standards for: DO, pH, TSS, NH_3-N, chlorine, flow, and C-BOD. Table 57 contains effluent limits for the Trail Tree wastewater treatment plant (WWTP). Trail Tree has violated its discharge limits only one time during the years of observation (Table 58). The only issues of concern noted by IDEM inspectors included a blocked aeration line and solids in the standpipe south of State Road 114 (R.D. Alley, IDEM inspector, IDEM permit files).

TABLE 57. Effluent limitations and monitoring requirements for the Trail Tree Plaza wastewater treatment plant.

Parameter	Monthly Average Load	Monthly Average Concentration
C-BOD	2.1 lb/d; 3.2 lb/d (summer); 5.3 lb/d (winter)	10 mg/l; 15 mg/l (summer); 25 mg/l (winter)
TSS	2.1 lb/d; 3.8 lb/d (summer); 6.4 lb/d (winter)	10 mg/l; 18 mg/l (summer); 30 mg/l (winter)
NH_3-N	0.23 lb/d (summer); 0.34 lb/d (winter)	1.1 mg/l (summer); 1.6 mg/l (winter)
Parameter	**Daily Minimum**	**Daily Maximum**
DO	6.0 mg/l (summer); 5.0 mg/l (winter)	--
pH	6	9
Residual Chlorine	--	0.02 mg/l

Source: Trail Tree Plaza NPDES Permit #IN0041904.

TABLE 58. Number of times and percentage of time the Trail Tree wastewater treatment plant was in violation of its permit for chemical discharge from June 2000-July 2001.

Parameter	Number of Times Violation Occurred	% of Time Plant was in Violation
C-BOD	0	--
TSS	0	--
NH_3-N	1	7%
DO	0	--
pH	0	--

Source: EPA's Envirofacts Warehouse database.

Confined Feeding Operation Discussion

Three separately owned farms are currently regulated by IDEM as confined feeding operations (CFO) within the Curtis Creek Watershed. CFOs are defined by the state of Indiana as those operations where animals are confined for more than 45 consecutive or non-consecutive days per year, a majority (>50%) of the confinement area is non-vegetated, and the number of animals exceeds 300 cattle, 600 swine, 600 sheep, or 30,000 fowl (IDEM, 2002). CFOs must operate within predetermined performance standards. The standards have four main targets: to avoid management practices which discharge pollutants to state's waters; to minimize non-point source pollution to state's waters; to design, construct, and maintain waste management systems to prevent the discharge of manure and other controlled waste; and to stage and apply manure in a manner which prevents nutrient runoff, ponding, or spills and minimizes nutrient leaching beyond the root zone.

Each of the CFOs in operation within the Curtis Creek Watershed have completed the IDEM confined feeding operation application. The application must include a completed application form, plat maps locating the confined feeding operation, waste management system drawings, information from a minimum of two soil test holes, and engineer-certified drawings for any new earthen, liquid manure storage structures. Additionally, the application must contain a farmstead plan and a manure management plan. The farmstead plan must accurately indicate locations of all existing structures and land features such as residences, surface waters, drainage inlets, roads, wells, and property boundaries and any existing or proposed waste management systems which include manure storage structures, transfer and treatment systems, feedlots, confined buildings, and waste storage and treatment systems (IDEM, 2002). Complete manure management plans contain procedures for manure and soil testing, methods for manure application, and agreements with owners of properties where off-site land application will occur. The manure management plan should provide adequate information to determine the theoretical annual volume of manure produced, the capacity required to provide 180 days of manure storage with contingency space for a 24-hour, 25-year rain event, and the acreage required for land application (Purdue Cooperative Extension Agency, 1998). Each of the CFOs manages different volumes of manure annually. The total manure volume is determined by the type of animal, the number of animals maintained, and the nutrient and mineral content of animal feed. Table 59 displays the average volume of solid and liquid manure produced by cattle and swine daily and annually. (Because dairy cattle and swine are the two types of confined feeding operations present in the Curtis Creek Watershed production values for these animals are displayed.)

TABLE 59. Average daily and annual solid and liquid manure production volumes.

Animal	Daily Solid Manure Production	Daily Liquid Manure Production	Annual Solid Manure Production	Annual Liquid Manure Production
Dairy cow	1.83 ft^3/d	2.20 ft^3/d	667.95 ft^3/yr	803 ft^3/yr
Swine				
Nursery	0.02 ft^3/d	0.05 ft^3/d	7.3 ft^3/yr	18.25 ft^3/yr
Finishing	0.08 ft^3/d	0.18 ft^3/d	29.2 ft^3/yr	65.7 ft^3/yr
Farrowing	0.21 ft^3/d	0.51 ft^3/d	76.65 ft^3/yr	186.15 ft^3/yr
Breeding	0.09 ft^3/d	0.16 ft^3/d	32.85 ft^3/yr	58.4 ft^3/yr

Source: IDEM, 2002.

All waste including bedding materials, urine, milking parlor and barn wash water, and any runoff that enters storage tanks must be handled as manure and is pumped into manure storage tanks. Each CFO must provide a minimum of 120 days of manure storage. Generally, solid and liquid manure is stored and applied separately. CFO operators base manure application rates on soil-available nitrogen and recommended agronomic nitrogen rates. Prior to April 2002, manure application rates were based on a recommended agronomic nitrogen rate of 150 pounds per acre (Purdue Cooperative Extension Agency, 1998). IDEM initially regulated all of the CFOs in the Curtis Creek Watershed at the 150 pounds of nitrogen per acre rate. Using this nitrogen goal each acre can be supplemented with manure from three dairy cows or 13 farrowing or 25 finishing pigs (Table 60). After April 2002, IDEM required CFO operators to recalculate manure application rates based on the intended cover crop and the soil-available nitrogen. Table 59 shows typical plant available nitrogen values utilized for manure application rate calculations following the April 2002 rule change (IDEM, 2002). Recalculated average manure application rates indicate that former application rates supplied more nitrogen to the soil than the plants could utilize. The practice of over-fertilizing often allows nitrogen and phosphorus to accumulate in the soil. This accumulation can create an imbalance of nutrients resulting in poor plant growth or lead to high levels of nitrogen and phosphorus loading to drainage tiles and surface waters from direct runoff or from soil leaching (Sutton, 1994; Wang et. al, 2002).

TABLE 60. Average manure application rates and acreage requirements for application of manure produced by the minimum number of animals. The calculation assumes that the minimum number of animals are maintained (300 dairy cattle or 600 swine).

Animal	Animal Capacity (# animals/acre)	Required Acreage
Dairy cow	3	100 acres
Swine		
Nursery	80	7.5 acres
Finishing	17	35.3 acres
Farrowing	13	46.2 acres
Breeding	25	24 acres

Source: Purdue Cooperative Extension Agency, 1998.

TABLE 61. Typical plant available nitrogen values utilized for manure application rate calculations following April 2002.

Crop	Plant Available Nitrogen Requirements
Corn	150 lb/acre
Soybeans	100 lb/acre
Hay/grass	100 lb/acre
Small grains	100 lb/acre
Set aside	100 lb/acre

Source: IDEM, 2002.

Korniak Farms operates an IDEM-regulated confined feeding operation located at 6262 South County Road 900 West (Figure 36). The property drains to Yeoman Ditch which lies 69 feet from the northern property boundary. Korniak Farms is permitted to house 1,817 swine which produce approximately 143,500 ft^3 of manure annually (Table 62; IDEM CFO Log #651). Manure is applied twice annually to 386.8 acres of landed owned and maintained by Korniak Farms (Figure 36). Korniak Farms manure application rates are set to supply 150 pounds of nitrogen per acre because their application was filed prior to April 2002. During the next application renewal cycle Korniak Farms must recalculate manure application rates based on soil type, plant available nitrogen, and cover crop. IDEM inspectors have not noted any spills or violations during Korniak Farms' eight years of operation (manure management plan approved January 30, 1995).

TABLE 62. Number and type of swine and average manure production rates for Korniak Farms.

Animal	Number of animals permitted	Average daily solid manure production	Average daily liquid manure production	Average annual solid manure production	Average annual liquid manure production
Nursery	600	12 ft^3/d	30 ft^3/d	4,380 ft^3/yr	10,950 ft^3/yr
Finishing	980	78.4 ft^3/d	176.4 ft^3/d	28,616 ft^3/yr	64,386 ft^3/yr
Farrowing	79	16.6 ft^3/d	40.3 ft^3/d	6,059 ft^3/yr	14,710 ft^3/yr
Breeding	158	14.2 ft^3/d	25.3 ft^3/d	5,183 ft^3/yr	9,235 ft^3/yr
Totals	**1,817**	**121.2 ft^3/d**	**272 ft^3/d**	**44,238 ft^3/yr**	**99,280 ft^3/yr**

Source: IDEM CFO Files, Log #651.

Cambalot Swine Breeders, Inc. operate an IDEM-regulated CFO located at 609 North State Road 55 (Figure 36). The farm drains to Elijah Ditch which transverses the property 150 feet from the primary storage lagoon. Cambalot is permitted to maintain 5,225 swine which produce approximately 442,600 ft^3 of manure annually (Table 63; IDEM CFO File Log #3535). Manure is stored in a liquid storage lagoon and injected in adjacent farm fields twice yearly at rates which supply 150 pounds of nitrogen per acre. Manure is applied on Cambalot owned land and on land where manure leases are maintained, some of which lies outside of the Curtis Creek Watershed. No spills or violations have been noted by IDEM inspectors during Cambalots' 15 years of operation.

TABLE 63. Number and type of swine and average manure production rates for Cambalot Swine Breeders, Inc.

Animal	Number of animals permitted	Average daily solid manure production	Average daily liquid manure production	Average annual solid manure production	Average annual liquid manure production
Nursery	1000	20 ft^3/d	50 ft^3/d	7,300 ft^3/yr	18,250 ft^3/yr
Finishing	3,700	296 ft^3/d	666 ft^3/d	108,040 ft^3/yr	243,090 ft^3/yr
Farrowing	80	16.8 ft^3/d	40.8 ft^3/d	6,132 ft^3/yr	14,892 ft^3/yr
Breeding	420	37.8 ft^3/d	67.2 ft^3/d	13,797 ft^3/yr	24,528 ft^3/yr
Boars	25	5.25 ft^3/d	12.75 ft^3/d	1,916 ft^3/yr	4,654 ft^3/yr
Totals	**5,225**	**376 ft^3/d**	**837 ft^3/d**	**137,185 ft^3/yr**	**305,414 ft^3/yr**

Source: IDEM CFO files, File Log #3535.

The Fair Oaks Dairy Farm operates confined feeding operations at six independently regulated locations throughout the Headwaters and Fair Oaks Subwatersheds (Figure 36; Table 64). (The final two barns have not been constructed; therefore, the barns are not currently in operation.) Each of the locations maintains a herd of 3,000 dairy cattle or a total herd of 12,000 cows (Table 64). Two additional barns housing 3,000 dairy cattle have been permitted for construction and operation by IDEM. Fair Oaks Dairy eventually plans to expand production to eight facilities housing a total of 24,000 dairy cattle. Permits have not yet been issued for the seventh and eighth barns. Each of the six facilities operates in the same general manner. Each location contains two wet dairy stall barns which house 1,250 cows each and one dry dairy stall barn which houses 500 cows, concrete manure storage pits, synthetically lined storage lagoons, a milking center and holding area, an earthen, synthetically lined lagoon and sand separators for the storage of milking center wastewater, a concrete silage pad, and a concrete storage pad.

Each Fair Oaks Dairy facility employs both a solid and liquid manure storage system. Solid manure is stored in the pit manure storage facilities at each site; each storage facility provides 120 days of storage or a total volume of 257,650 ft^3 of solid manure storage. The liquid system stores milking barn wastes. It consists of an earthen pond with a synthetic liner which provides 430,000 ft^3 of liquid waste storage. Fair Oaks annually produces an average of 2,012,520 ft^3 of manure at each facility or a total of 8,050,080 ft^3 of solid and liquid manure (Table 64; IDEM CFO Files, Log #6015, #6036, #6064, #6065, #6110, and #6153). Fair Oaks Dairy utilizes a runoff diversion system that employs ditches, levees, concrete curbs, and natural drainage to prevent precipitation and runoff from entering the solid and liquid manure storage systems. Manure from the solid storage system is spread daily utilizing spreader boxes, while liquid manure is spread a minimum of four times per year with a mobile, irrigation system. Fair Oaks spreads manure on 10,400 acres of both dairy-owned and off site land, some of which lies outside of the Curtis Creek Watershed (Figure 36). Fair Oaks utilizes runoff controls such as levees, buffer strips, contour tillage, crop residue, straw bales, and silt fences to prevent surface runoff from entering drainage tiles and surface inlets. In Fair Oaks Dairy's four year operating history, IDEM has noted only one spill or violation (IDEM CFO files). The spill impacted an 8,000 ft^2 area in a drainage ditch on the west side of County Road 600 East one-eighth of a mile north of State Road 14. IDEM employees found no trace of manure or dead fish two days after the incident. No other spills or violations have been noted by IDEM.

TABLE 64. Fair Oaks Dairy operating locations and information. Barn #5 and barn #6 are not currently in operation. Fair Oaks Dairy has satisfied all IDEM requirements for construction; therefore, the total annual manure production capacity and land available for manure application is included in this table.

Dairy operation	Location	Number of animals	Average annual manure production	Acreage available for application
North (#1)	CR 600 N	3,000	2,012,519 ft^3/yr	1,600 acres
South (#2)	CR 600 E	3,000	2,012,519 ft^3/yr	2,300 acres
Central (#3)	CR 400 E/CR 300 N	3,000	2,012,519 ft^3/yr	1,600 acres
West (#4)	CR 400 E/CR 500 N	3,000	2,012,519 ft^3/yr	1,600 acres
Totals for barns in operation		**12,000**	**8,050,080 ft^3/yr**	**7,100 acres**
#5	CR 400 E/CR 500 N	3,000	2,012,519 ft^3/yr	1,600 acres
#6	CR 200 N	3,000	2,012,519 ft^3/yr	1,700 acres
Totals for all barns		**18,000**	**12,075,114 ft^3/yr**	**10,400 acres***

Source: IDEM CFO files, File Log #6015, #6036, #6064, #6065, #6110, and #6053.
*Not all of this area is within the Curtis Creek Watershed.

Watershed Investigation Summary

The goal of the watershed investigation was to identify areas of concern and select sites for future management. Locations identified during both the aerial and windshield tours where certain land use management practices are relevant and applicable appear in Figure 36. The aerial tour pointed out areas where filter strip implementation and livestock fencing could benefit water quality especially in the Yeoman Ditch, Long Ditch, and Elijah Ditch Subwatersheds. Grassed waterway construction or maintenance may be possible in the Headwaters, County Road 100 South, and State Road 114 Subwatersheds. Areas for wetland restoration in five of the study subwatersheds were also noted from the air. Additional areas for BMP implementation were documented during the windshield survey including opportunities for: filter strip application, bank stabilization, livestock fencing, revegetation of eroded/disturbed areas, and grassed waterway installation. Some potential contributors to point and/or non-point source pollution were also documented during the windshield tour. No sampling was conducted to determine pollutant contribution, but potential sources included: three WWTPs, a golf course, and three confined feeding operations.

Stream Assessment

Introduction

The stream assessment portion of the watershed study consisted of water chemistry sampling during base flow and a storm runoff event, a macroinvertebrate community assessment, and a habitat assessment. Sampling was conducted at ten sites in the Curtis Creek Watershed (Figure 41). The stream assessment study provides information on water quality and aquatic habitat health. The data assists in guiding the prioritization of management actions and directing those actions toward the most critical areas.

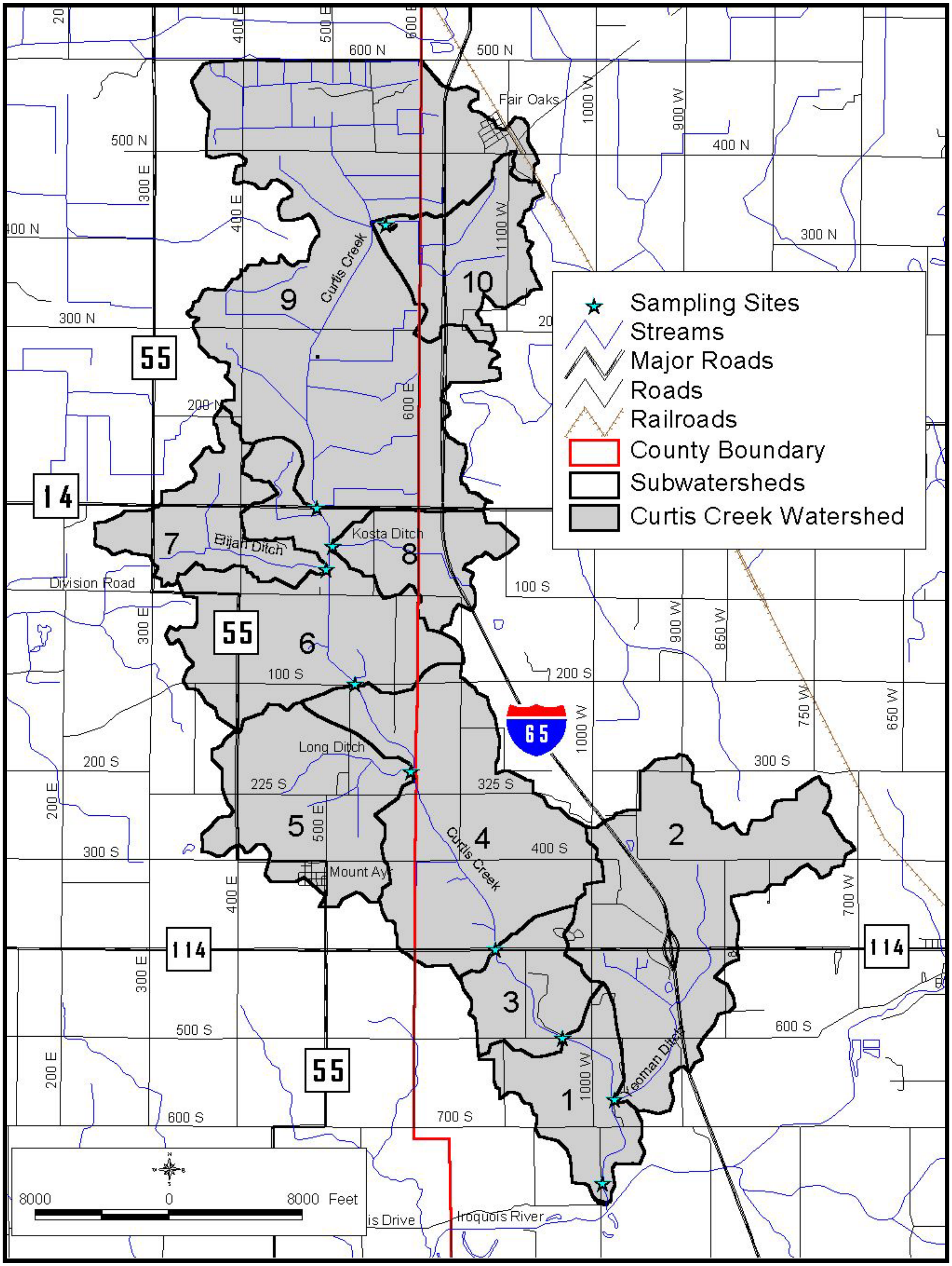


FIGURE 41. Sample site locations.

Sampling Locations

Ten stream sites were strategically chosen throughout the Curtis Creek Watershed (Figure 41; Table 65). These sites were selected based on accessibility and input from the Newton County SWCD. Ideally, the stream assessment protocol would include sampling at a reference site for comparative purposes. An ideal reference site would lie in relatively undisturbed watershed and would meet all criteria listed in Table 66. However, because of extensive human activities throughout the study watershed, a reference site meeting all criteria in Table 66 could not be located.

TABLE 65. Detailed sampling location information for the Curtis Creek Watershed sampling sites.

Site #	Stream Name	Subwatershed	Road Location	Place Sampled	Latitude	Longitude
1	Curtis Creek	Mouth	east of CR 1000 W and north of Iroquois Drive	upstream of foot bridge	N40° 30' 38.2"	W87° 17' 58.0"
2	Yeoman Ditch	Yeoman Ditch	east of CR 1000 W and north of CR 700 S	upstream of Curtis Creek confluence	N40° 55' 00.7"	W87° 13' 58.7"
3	Curtis Creek	Golf Course	intersection of CR 500 S	north side of CR 500 S	N40° 55' 35.3"	W87° 14' 38.1"
4	Curtis Creek	SR 114	intersection of SR 114	north side of SR 114	N40° 55' 34.3"	W87° 15' 08.8"
5	Long Ditch	Long Ditch	east of CR 525 E and north of CR 225 S	upstream of Curtis Creek confluence	N40° 57' 56.7"	W87° 16' 33.5"
6	Curtis Creek	CR 100 S	intersection of CR 100 S	north side of CR 100 S	N40° 59' 02.2"	W87° 17' 20.6"
7	Elijah Ditch	Elijah Ditch	east of CR 400 E and south of SR 14	upstream of Curtis Creek confluence	N41° 00' 10.0"	W87° 17' 44.8"
8	Kosta Ditch	Kosta Ditch	west of 600 E and south of SR 14	upstream of Curtis Creek confluence	N41° 00' 24.0"	W87° 17' 41.3 "
9	Curtis Creek	Headwaters	intersection of SR 14	north side of SR 14	N41° 01' 15.7"	W87° 17' 29.6"
10	Unnamed tributary	Fair Oaks	north of CR 300 N and west of CR 600E	upstream of Curtis Creek confluence	N41° 03' 34.2"	W87° 17' 05.0"
Ref	Beaver Creek	Beaver Creek	intersection of CR 600W	upstream of CR 600 W	N40° 57' 10.5"	W87° 30' 28.2"

TABLE 66. Minimum criteria for stream reference sites.

Example Criteria for Reference Sites (Must meet all criteria)
• pH >=6; if blackwater stream, then pH <=6 and DOC >8 mg/l • Dissolved Oxygen >= 4 ppm • Nitrate <=16.5 mg/l • Urban land use <=20% of catchment area • Forest land use >=25% of catchment area • Instream habitat rating optimal or suboptimal • Riparian buffer width >=15m • No channelization • No point source discharges

Source: Plafkin et al., 1999.

State personnel have suggested two streams that offer potential for use as reference sites: Stoney Creek near Muncie, Indiana and Otter Creek near Terre Haute, Indiana. However, neither of these two streams is located within the same ecoregion as the study area. Because of their location within difference ecoregions, the relevance of comparing Stoney or Otter Creeks with Curtis Creek is limited.

Simon (1991) identified six potential reference sites located within the Iroquois River Watershed. These reference sites are not undisturbed or pristine but represent the best possible conditions given the extensive amount of human activities throughout the study watershed. Most of these sites do not meet the criteria listed in Table 66. However, Beaver Creek located northwest of Morocco was chosen as a reference site based on the Beaver Creek Watershed size at this location and its proximity to the Curtis Creek Watershed. Its relatively good water quality, undisturbed watershed, and natural channel form at the sampling location make comparing Beaver Creek with Curtis Creek relevant.

Water Chemistry

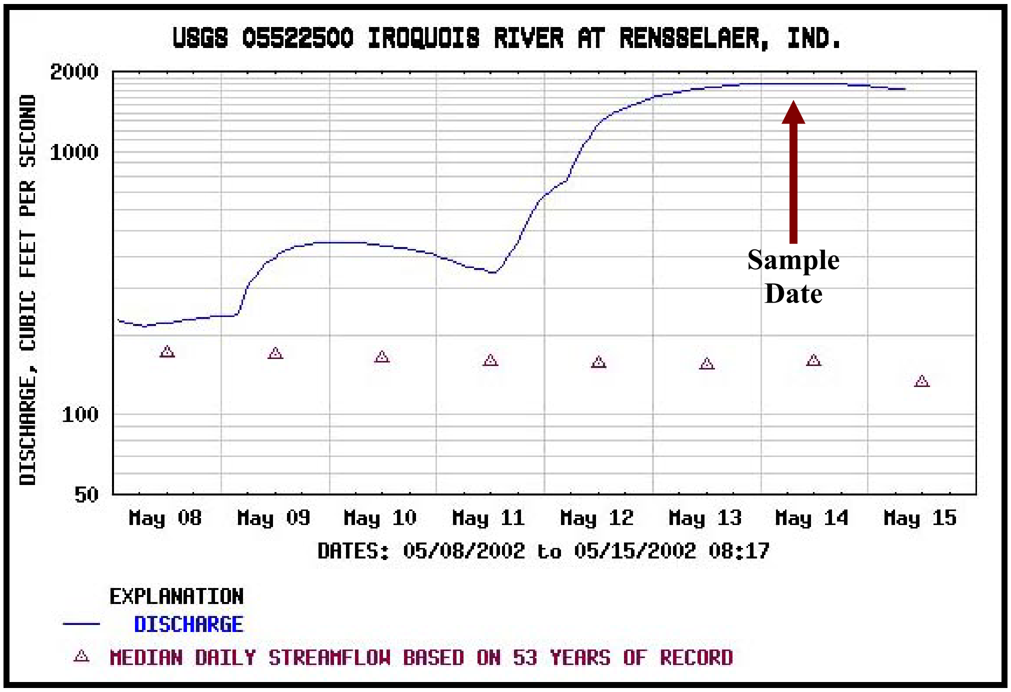
Water Chemistry Methods

The LARE sampling protocol requires assessing water quality of each stream site once during base flow and once during storm flow. Base flow sampling provides an understanding of the typical conditions in the streams. Following storm events, increased overland flow results in increased erosion of soil and nutrients from the land. Stream concentrations of nutrients and sediment are typically higher following storm events. Storm sampling provides a "worst case" scenario picture of watershed pollutant loading.

For this study, storm event samples were initially collected May 14, 2002 following a storm that dumped 2.7 inches of rain in a 24-hour period and nearly 4 inches in a 7-day period. However, due to high water levels, it was impossible to accurately measure discharge at a majority of the sampling sites. The Iroquois River stage during the flood event peaked at nearly 2,000 cubic feet per second on the day of sample collection (Figure 42). Appendix 6 lists physical and chemical constituents measured during the flood event.

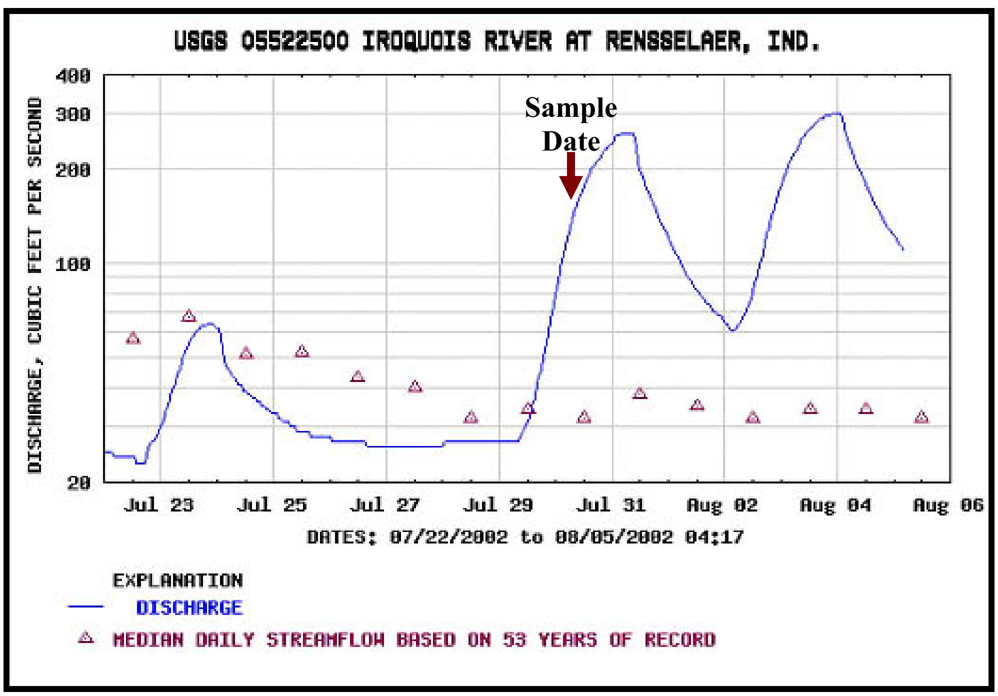
JFNew chose to not use water quality samples collected on May 14 for two reasons: 1) the inaccuracy associated with discharge measurement would not allow for accurate calculation of pollutant loading and 2) nutrient, sediment, and *E. coli* concentrations measured during the flood event were not representative of a typical storm event in Newton and Jasper Counties. Therefore, JFNew collected a second set of storm samples during a more typical storm event for Newton and Jasper Counties. The second set of storm event samples were collected July 30, 2002 following a 24-hour, 1.86 inch rain event. River stage on July 30, 2002 exceeded the historic median daily storm flow (Figure 43). Appendix 6 contains physical and chemical constituents measured during the storm event.

Base flow samples were collected June 24-25, 2002 following a period of little precipitation. River stage at the Iroquois River was below the historic median daily stream flow (Figure 44), therefore this sampling date is representative of base flow conditions. It is important to note that even though these water quality samples provide insight into the characteristics of the streams at the particular time of sampling, it is difficult to extrapolate these results to other times of the year and different conditions. Appendix 6 contains physical and chemical constituents measured during base flow sampling.



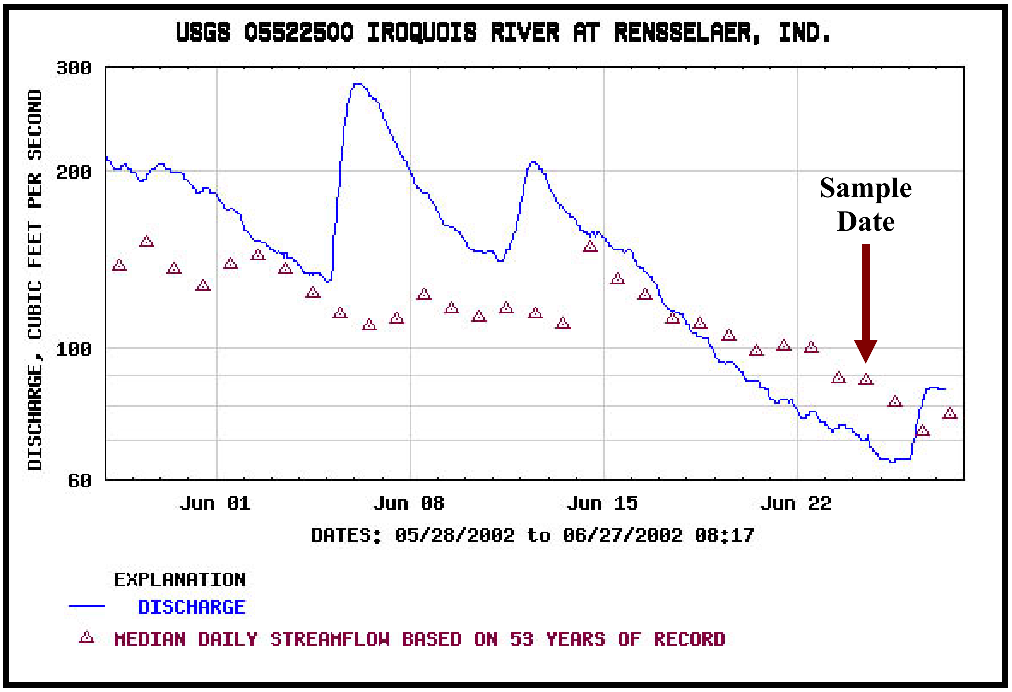
Source: USGS website (http://www.usgs.gov)

FIGURE 42. Discharge in the Iroquois River immediately upstream of the confluence with Curtis Creek. The arrow marks the discharge in the Iroquois River on the date "flood" flow sampling was attempted. Discharge on the sampling date exceeded flood stage.



Source: USGS website (http://www.usgs.gov)

FIGURE 43. Discharge in the Iroquois River immediately upstream of the confluence with Curtis Creek. The arrow marks the discharge in the Iroquois River on the storm flow sampling date. Discharge on the sampling date exceeded the 53-year median stream flow.



Source: USGS website (http://www.usgs.gov)

FIGURE 44. Discharge in the Iroquois River immediately upstream of the confluence with Curtis Creek. The arrow marks the Iroquois River discharge on the base flow sampling date. Discharge on the sampling date fell below the 53-year median stream flow.

Base flow and stormwater runoff sampling included measurements of physical, chemical, and bacteriological parameters. Conductivity, temperature, and dissolved oxygen were measured *in situ* at each stream site with an YSI Model 85 meter. (Conductivity was measured during base flow sampling only.) Water velocity was measured using a Marsh-McBirney Flo-Mate current meter. Cross-sectional area of the stream channel at each site was measured and discharge calculated by multiplying water velocity by the cross-sectional areas. In addition, water samples were collected from just below the water surface using a cup sampler and analyzed for the following parameters:

- pH
- alkalinity
- total phosphorus (TP)
- soluble reactive phosphorus (SRP)
- nitrate-nitrogen (NO_3^-)
- ammonia-nitrogen (NH_3)
- total Kjeldahl nitrogen (TKN)
- total suspended solids (TSS)
- *E. coli* bacteria

Following collection, samples were stored in an ice chest until analysis in the Indiana University School of Public and Environmental Affairs (IUSPEA) laboratory in Bloomington, Indiana. The *E. coli* samples were taken to the Jasper County Hospital for analysis. All sampling techniques and laboratory analysis methods were performed in accordance with procedures in *Standard*

Methods for the Examination of Water and Wastewater, 20th Edition (APHA, 1998). Appendix 6 provides copies of the laboratory data for the samples.

The comprehensive evaluation of watersheds requires collecting data the different water quality parameters listed above. A brief description of each of the parameters follow:

Temperature Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. Likewise, water temperature regulates the species composition and activity of life associated with the environment. Since essentially all aquatic organisms are 'cold-blooded' the temperature of the water regulates their metabolism and ability to survive and reproduce effectively (EPA, 1976). The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits to protect aquatic life for Indiana streams. Temperatures during the month of May should not exceed 80 ^{o}F (23.7 ^{o}C) by more than 3 ^{o}F (1.7 ^{o}C). June and July temperatures should not exceed 90 ^{o}F (32.2 ^{o}C). The code also states that the "maximum temperature rise at any time or place… shall not exceed 5 ^{o}F (2.8 ^{o}C) in streams…"

Dissolved Oxygen (DO) DO is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need water to possess a DO concentration of at least 3-5 parts per million (ppm). Cold-water fish such as trout generally require higher concentrations of DO than warmwater fish such as bass or bluegill. The IAC sets minimum DO concentrations at 5 mg/1 for warmwater fish. DO enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with DO. Waterbodies overloaded with algae and macrophytes often exhibit supersaturation due to the high levels of photosynthesis. Dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1998). During low discharge, conductivity is higher than it is following a storm water runoff because the water moves more slowly across or through ion containing soils and substrates during base flow. Carbonates and other charged particles (ions) dissolve into the slow-moving water, thereby increasing conductivity levels.

pH The pH of stream water describes the concentration of acidic ions (specifically H^{+}) present in the water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6-9 pH units for the protection of aquatic life.

Alkalinity Alkalinity is a measure of the acid-neutralizing (or buffering) capacity of water. Certain substances in water, like carbonates, bicarbonates, and sulfates, can cause the water to resist changes in pH. A lower alkalinity indicates a lower buffering capacity or a decreased ability to resist changes in pH. During base flow conditions, alkalinity is usually high because the water picks up carbonates from the bedrock. Alkalinity measurements are usually lower during storm flow conditions because buffering compounds are diluted by rainwater and the runoff water moves across carbonate-containing bedrock materials so quickly that little carbonate is dissolved to add additional buffering capacity.

Turbidity Turbidity (measured in Nephelometric Turbidity Units) is a measure of water coloration and particles suspended in the water. It is generally related to suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. According to the Hoosier Riverwatch, the average turbidity of an Indiana stream is 11 NTU with a typical range of 4.5-17.5 NTU (White, unpublished data). Turbidity measurements >20 NTU have been found to cause undesirable changes in aquatic life (Walker, 1978).

Nitrogen Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of the air we breathe is nitrogen gas. Nitrogen gas diffuses into water where it can be "fixed", or converted, by blue-green algae to ammonia for their use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because of this, there is an abundant supply of available nitrogen to aquatic systems. The three common forms of nitrogen are:

Nitrate (NO_3) – Nitrate is an oxidized form of dissolved nitrogen that is converted to ammonia by algae. It is found is streams and runoff when dissolved oxygen is present, usually in the surface waters. Ammonia applied to farmland is rapidly oxidized or converted to nitrate and usually enters surface and groundwater as nitrate. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams classified as modified warmwater habitat (MWH) was 1.6 mg/1. Modified warmwater habitat was defined as: the aquatic life use assigned to streams that have irretrievable, extensive, man-induced modification that preclude attainment of the warmwater habitat use (WWH) designation; such streams are characterized by species that are tolerant of poor chemical quality (fluctuating dissolved oxygen) and habitat conditions (siltation) that often occur in modified streams (Ohio EPA, 1999). Nitrate concentrations exceeding 10 mg/1 in drinking water are considered hazardous to human health (Indiana Administrative Code IAC 2-1-6).

Ammonia (NH_3) – Ammonia is a form of dissolved nitrogen that is the preferred form for algae use. Bacteria produce ammonia as they decompose dead plant and animal matter. Ammonia is the reduced form of nitrogen and is found in water where dissolved oxygen is lacking. Important sources of ammonia include fertilizers and animal manure. Both temperature and pH govern the toxicity of ammonia for aquatic life. According to the IAC, maximum unionized ammonia concentrations within the temperature and pH ranges measured for the study streams should range between approximately 0.13 and 0.22 mg/1.

Organic Nitrogen (Org N) – Organic nitrogen includes nitrogen found in plant and animal materials. It may be in dissolved or particulate form. In the analytical procedures, total Kjeldahl nitrogen (TKN) was analyzed. Organic nitrogen is TKN minus ammonia.

Phosphorus Phosphorus is an essential plant nutrient, and the one that most often controls aquatic plant (algae and macrophyte) growth. It is found in fertilizers, human and animal wastes, and yard waste. There are few natural sources of phosphorus to streams other than that which is attached to soil particles; there is no atmospheric (vapor) form of phosphorus. For this reason, phosphorus is often a ***limiting nutrient*** in aquatic systems. This means that the relative scarcity of phosphorus may limit the ultimate growth and production of algae and rooted aquatic plants. Management efforts often focus on reducing phosphorus inputs to receiving waterways because: (a) it can be managed and (b) reducing phosphorus can reduce algae production. Two common forms of phosphorus are:

Soluble reactive phosphorus (SRP) – SRP is dissolved phosphorus readily usable by algae. SRP is often found in very low concentrations in phosphorus-limited systems where the phosphorus is tied up in the algae themselves. Because phosphorus is cycled so rapidly through biota, SRP concentrations as low as 0.005 mg/l are enough to maintain eutrophic or highly productive conditions in lake systems (Correll, 1998). Sources of SRP include fertilizers, animal wastes, and septic systems.

Total phosphorus (TP) – TP includes dissolved and particulate phosphorus. TP concentrations greater than 0.03 mg/1 (or 30µg/1) can cause algal blooms. TP is often a problem in agricultural watersheds because TP concentrations required for eutrophication control are an order of magnitude lower than those typically measured in soils used to grow crops (0.2-0.3 mg/l). The Ohio EPA (1999) found that the median TP in wadeable streams that support MWH for fish was 0.28 mg/1.

Total Suspended Solids (TSS) A TSS measurement quantifies all particles suspended in stream water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in stream water. In general, the concentration of suspended solids is greater during high flow events due to increased overland flow. The increased overland flow erodes and carries more soil and other particulates to the stream. The State of Indiana does not have a TSS standard. In general, TSS concentrations >80 mg/1 have been found to be deleterious to aquatic life (Waters, 1995).

***E. coli* Bacteria** *E. coli* is one member of a group of bacteria that comprise the fecal coliform bacteria group and is used as an indicator organism to identify the potential for the presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments, and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum standard at 235-colonies/100 ml in any one sample.

Water Chemistry Results

Introduction

There are two useful ways to report water quality data in flowing water. Concentrations describe the mass of a particular material contained in a unit of water, for example, milligrams of phosphorus per liter (mg/l). Mass loading (in units of kg/day) on the other hand describes the mass of a particular material being carried per unit of time. For example, a high concentration of phosphorus in a stream with very little flow will deliver a smaller total amount of phosphorus to the receiving waterway than will a stream with a low concentration of phosphorous but a high flow of water. It is the total amount (mass) of phosphorus, solids, and bacteria actually delivered from the watershed that is most important when considering the effects of these materials downstream. Because consideration of concentration and mass loading data is important, the following three sections will discuss 1) physical parameter concentrations, 2) chemical and bacterial parameter concentrations, and 3) chemical and sediment parameter mass loading.

Physical Concentrations and Characteristics
Physical parameter results measured during base and storm flow sampling are presented in Table 67. Stream discharges measured during base and storm flow conditions are shown in Figure 45. Each physical parameter is addressed in the following discussion.

TABLE 67. Physical parameter data collected during stream chemistry sampling events in the Curtis Creek Watershed on 6/24/2002, 6/25/2002, and 7/30/2002. Shaded squares indicate those samples that were in violation of Indiana state standards and/or generally accepted water quality values.

Site	Date	Timing	Flow (cfs)	Temp (°C)	DO (mg/l)	DO Sat. (%)	Conductivity (µmhos)	pH	Alkalinity (mg/l)	Turbidity (NTU)
1	6/24/02	Base	7.0	22.5	7.62	87.5	600	7.9	208	5.5
	7/30/02	Storm	135.5	21.5	5.39	60.5	*	7.5	125	26.0
2	6/24/02	Base	3.6	23.0	7.84	91.4	800	8.0	250	4.3
	7/30/02	Storm	6.0	21.2	4.78	53.6	*	7.5	148	22.0
3	6/24/02	Base	6.2	24.3	8.43	99.6	600	8.0	197	4.5
	7/30/02	Storm	123.9	21.4	5.69	63.8	*	7.4	131	20.0
4	6/24/02	Base	2.7	24.2	5.53	65.9	780	7.9	272	12.0
	7/30/02	Storm	--	21.7	5.37	61.1	*	7.4	134	17.0
5	6/24/02	Base	1.3	18.1	6.94	73.4	600	7.9	232	6.5
	7/30/02	Storm	5.2	21.8	5.34	61.7	*	7.4	150	12.0
6	6/24/02	Base	3.7	21.9	2.16	24.7	580	7.7	216	3.3
	7/30/02	Storm	37.7	25.2	6.95	84.2	*	7.5	151	7.0
7	6/24/02	Base	1.2	22.9	7.91	92.4	580	7.9	212	4.0
	7/30/02	Storm	1.1	24.6	5.35	63.3	*	7.5	170	4.0
8	6/24/02	Base	2.0	20.8	6.66	74.4	570	7.9	182	2.6
	7/30/02	Storm	5.9	23.4	6.34	74.6	*	7.5	123	5.0
9	6/24/02	Base	2.4	23.2	4.97	59.3	550	7.8	191	1.8
	7/30/02	Storm	15.0	24.6	7.90	92.7	*	7.6	170	2.0
10	6/24/02	Base	1.3	25.2	11.56	140.5	550	8.2	137	2.0
	7/30/02	Storm	6.2	24.1	6.76	80.4	*	7.7	135	1.0
Ref	6/24/02	Base	3.2	25.2	7.22	87.7	150	8.0	141	5.3
	7/30/02	Storm	75.3	25.5	5.97	73.1	*	7.8	168	14.0

* = Conductivity was only sampled during base flow event.

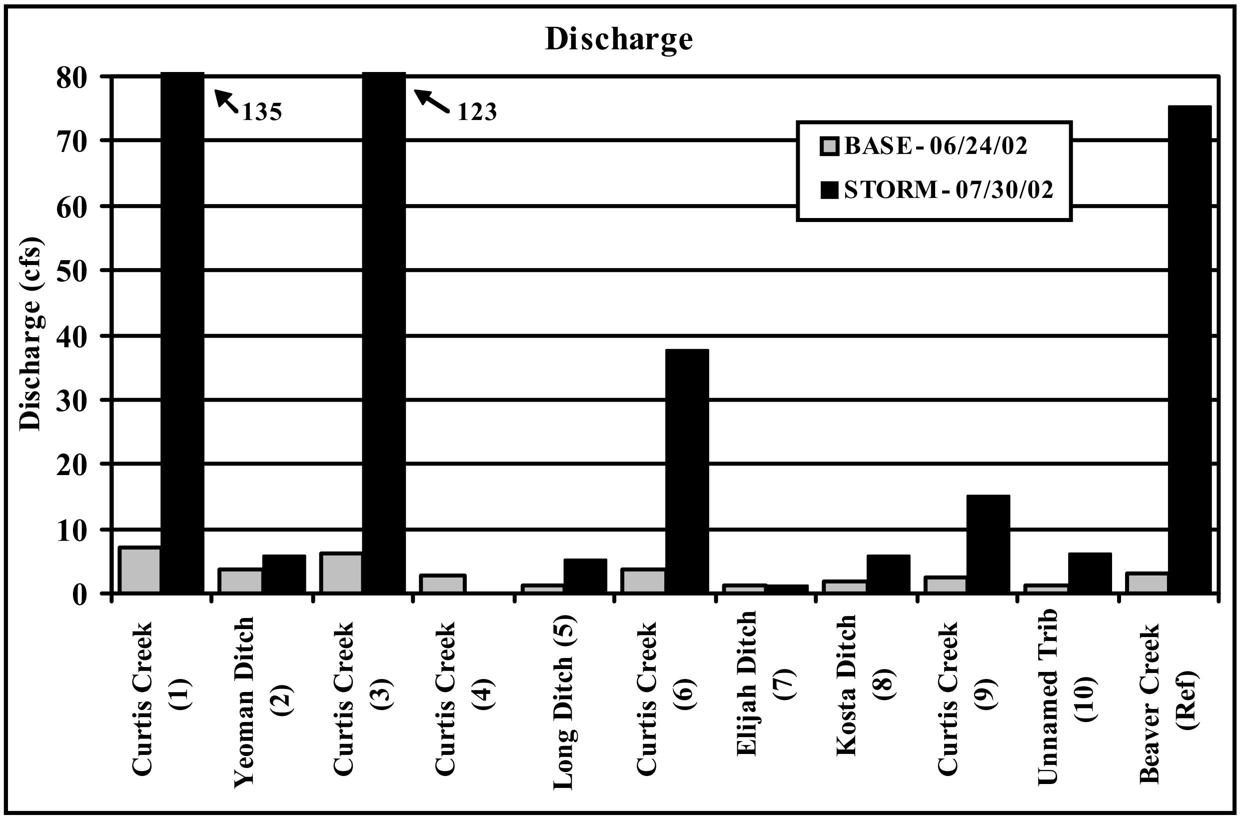


FIGURE 45. Discharge measurements during base flow and storm flow sampling of Curtis Creek Watershed streams.

During base flow conditions, temperatures in the creeks varied from 18.1 °C (64.6 °F) in Long Ditch (Site 5) to 25.2°C (77.4 °F) in the Unnamed Tributary (Site 10) and Beaver Creek (the Reference Site). Water temperatures during storm flow varied from 21.2 °C (70.1 °F) in Yeoman Ditch (Site 2) to 25.2 °C (77.4 °F) at in Curtis Creek (Site 6). All temperatures were within ranges suitable for aquatic life. Those creeks with cooler temperatures, such as Curtis Creek in Jasper County, likely had a greater portion of groundwater flowing in them. Streamside vegetation that provides shading to the water can also prevent heat gain. The higher temperatures measured in some streams are likely due to shallow depth, lack of riparian shading, lower proportion of groundwater inputs, and/or point source inputs (like the McDonald's Wastewater Treatment Plant that discharges treated effluent to Yeoman Ditch).

Dissolved oxygen (DO) concentrations during base flow varied from 2.2 mg/l in Curtis Creek at CR 100 South (Site 6) to 11.6 mg/l in the Unnamed Tributary (Site 10) and from 4.8 mg/l in Yeoman Ditch (Site 2) to 6.9 mg/l in Curtis Creek at CR 100 South (Site 6) during storm flow. Dissolved oxygen concentrations measured at all sites except Curtis Creek at County Road 100 South (Site 6) and the Curtis Creek Headwaters (Site 9) during base flow exceeded the level required to support aquatic life (5 mg/l).

Because DO varies with temperature (cold water can contain more oxygen than warm water), it is relevant to consider DO saturation values. DO saturation refers to the amount of oxygen dissolved in water compared to the maximum possible when water is in equilibrium with the atmosphere and is saturated with oxygen. For example, 18°C water that is completely saturated with oxygen will have a DO concentration of 9.5 mg/l. 18°C water exhibits a DO concentration lower than 9.5 mg/l, than it is not completely saturated. Stream dissolved oxygen concentrations that are less than 100% saturated suggest that: a) decomposition processes within the stream consume oxygen more quickly than it can be replaced by diffusion from the atmosphere, and b) flow in the streams is not turbulent enough to entrain sufficient oxygen. Oversatuation occurs when in-stream processes add more oxygen to the water column than would be expected at a given temperature.

Dissovled oxygen saturation in the Curtis Creek Watershed streams averaged 81% during base flow and 69% during storm flow. The low dissolved oxygen concentration and saturation exhibited in Curtis Creek at CR 100 South (Site 6) is likely the result of decomposition processes and sluggish water velocity. Base flow sampling occurred at Site 6 early in the morning, a time when overnight respiration dominates the oxygen regime. Overnight respiration could have depleted the oxygen content of the water. Because Site 6 lacks the gradient necessary to induce turbulent flow, new oxygen is not added to the water column. The result is low dissolved oxygen concentration and low percent saturation. In contrast, supersaturation of dissolved oxygen was observed in the Unnamed Tributary (Site 10). This supersaturation is likely the result of excessive algal growth in response to high nutrient concentrations

Values of pH were well within the water quality standards range (6-9 units) established by the Indiana Administrative Code. pH levels during base flow were generally higher (7.7-8.2) than levels measure during storm flow conditions (7.5-7.8). During low water periods, stream water has more time to accrue buffering compounds from alkaline soils. Alkalinity measurements taken during base and storm flow conditions ranged from 125-272 mg/l and indicate that Curtis Creek Watershed streams are well buffered. Conductivity in Curtis Creek Watershed streams ranged from 550 μmhos at Curtis Creek Headwaters (Site 9) and the Unnamed Tributary (Site 10) to 800 μmhos at Yeoman Ditch (Site 2) during base flow.

Turbidity levels measured in the Curtis Creek streams exceeded the Indiana average turbidity (4.5-17.5 NTUs; White, unpublished) at only three sites during the storm event sampling. The highest turbidity (26 NTUs) was measured at Curtis Creek Mouth (Site 1), while the Unnamed Tributary (Site 10) during storm flow exhibited the lowest turbidity (1 NTU). Typically during storm flow, turbidity is greater in streams due to increased overland flow carrying suspended sediments into the creeks. Lower Curtis Creek (Site 1), Yeoman Ditch (Site 2), and Curtis Creek at CR 100 South (Site 6) were noticeably more turbid during storm sampling. Turbidity measurements during storm flow were elevated at all sites except Elijah Ditch (Site 7) and the Unnamed Tributary (Site 10). This increase in turbidity following storm events suggests that stormwater throughout the Curtis Creek Watershed carries larger amounts of dissolved and suspended solids.

Chemical and Bacterial Concentrations

Chemical and bacterial concentration data for the Curtis Creek watershed streams are listed by site in Table 68. Figures 46-53 present concentration information graphically.

TABLE 68. Chemical and bacterial characteristics of the Curtis Creek watershed stream samplings on 6/24/2002, 6/25/2002, and 7/30/2002. Additional E. coli samples were collected following a storm event on 3/26/2003 from three sites (Site 1, Site 9, and the Reference Site). Shaded squares indicate those samples that were in violation of Indiana state standards and/or generally accepted water quality values.

Site	Date	Timing	NO_3^--N (mg/l)	NH_3-N (mg/l)	TKN (mg/l)	SRP (mg/l)	TP (mg/l)	TSS (mg/l)	*E. coli* (#/100 ml)
1	6/24/02	Base	2.92	0.031	0.931	0.014	0.069	11.00	>2,400
	7/30/02	Storm	6.74	0.045	1.843	0.062	0.217	98.40	7,300
	3/26/03	Storm	--	--	--	--	--	--	81
2	6/24/02	Base	5.27	0.102	0.740	0.044	0.128	0.25	440
	7/30/02	Storm	6.23	0.132	1.619	0.114	0.304	66.80	2,900
3	6/24/02	Base	3.02	0.206	0.849	0.011	0.090	3.14	730
	7/30/02	Storm	6.66	0.035	1.593	0.061	0.172	64.50	5,500
4	6/24/02	Base	1.86	9.905	14.193	0.058	0.434	18.00	>2,400
	7/30/02	Storm	6.43	0.033	1.510	0.065	0.152	49.50	4,600
5	6/24/02	Base	9.99	0.145	0.328	0.065	0.137	2.25	1,100
	7/30/02	Storm	8.21	0.018*	1.047	0.117	0.190	23.00	12,000
6	6/24/02	Base	1.72	3.024	4.196	0.074	0.222	3.75	260
	7/30/02	Storm	4.94	0.048	1.115	0.037	0.103	31.00	830
7	6/24/02	Base	1.19	0.108	0.614	0.017	0.125	0.75	280
	7/30/02	Storm	7.15	0.018 *	0.968	0.028	0.072	10.00	780
8	6/24/02	Base	3.17	0.128	0.906	0.028	0.122	3.87	3,400
	7/30/02	Storm	3.59	0.129	1.452	0.069	0.142	11.60	2,200
9	6/24/02	Base	1.49	2.414	3.173	0.140	0.222	0.75	330
	7/30/02	Storm	3.28	0.018	0.877	0.022	0.052	9.75	420
	3/26/03	Storm	--	--	--	--	--	--	71
10	6/24/02	Base	8.61	0.078	0.731	0.010 *	0.044	2.25	84
	7/30/02	Storm	14.27	0.018 *	0.349	0.010 *	0.024	2.20	2,900
Ref	6/24/02	Base	3.07	0.056	0.783	0.024	0.078	3.80	NA
	7/30/02	Storm	8.71	0.046	1.710	0.046	0.145	50.00	NA
	3/26/03	Storm	--	--	--	--	--	--	200

NA = No Sample Collected
* Method Detection Limit

Nitrate-nitrogen concentrations in the Curtis Creek Watershed streams are illustrated in Figure 46. Nitrate-nitrogen concentrations at all but two sites, Elijah Ditch (Site 7) and Curtis Creek Headwaters (Site 9) during base flow conditions exceeded 1.6 mg/l, the median nitrate concentration of wadeable streams classified as modified warmwater habitat (MWH) in Ohio (Ohio EPA, 1999). The Ohio EPA uses 1.6 mg/l as its standard for the protection of aquatic life in modified warmwater habitat streams. The exceedence of this level in Curtis Creek Watershed streams suggests high nitrate-nitrogen levels in these streams may be limiting aquatic life in the streams. Storm water runoff concentrations were higher than base flow concentrations and varied from 3.3 mg/l at Curtis Creek Headwaters (Site 9) to 14.3 mg/l at the Unnamed Tributary (Site 10). Only the Unnamed Tributary (Site 10) during storm flow exceeded the IAC standard of 10 mg/l. Site 5 was the only site to possess higher nitrate concentrations during base flow than during storm runoff. Nitrate is highly soluble in water, so it is present in storm water and groundwater.

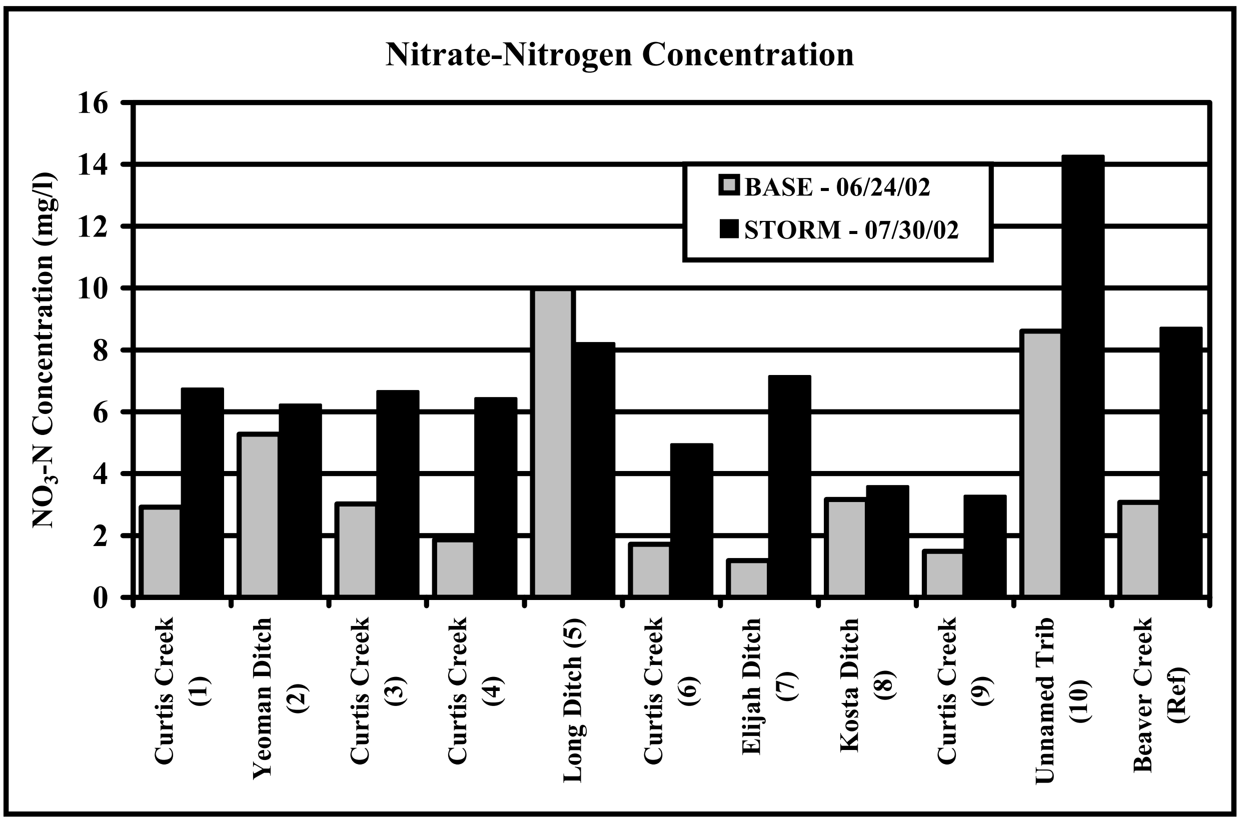


FIGURE 46. Nitrate-nitrogen concentration measurements during base flow and storm flow sampling of Curtis Creek Watershed streams.

Ammonia-nitrogen concentrations at most sites during base or storm flow did not exceed the maximum concentration set by the IAC for the protection of aquatic life. (The ammonia-nitrogen standard depends both on temperature and pH.) Curtis Creek at SR 114 (Site 4), at CR 100 South (Site 6), and the Headwaters (Site 9) were the exception. Ammonia-nitrogen concentrations during base flow at these sites exceeded the IAC standard based on their respective pH values and temperatures (Figure 47). High ammonia-nitrogen concentrations measured in Curtis Creek at the Headwaters, CR 100 South, and SR 114 coupled with relatively high particulate nitrogen (TKN) and phosphorus (TP) concentrations and relatively low dissolved oxygen levels imply that high levels of organic decomposition are occurring at these sites. Ammonia-nitrogen concentrations measured in Curtis Creek at SR 114 (Site 4) are disproportionally higher than those measured at the other nine sites. The concentrations measured at Site 4 are most likely not due to organic decomposition alone. Dissolved oxygen concentrations measured at this site (5.5 mg/l; 66% saturation) were not as low as those measured at Site 6 (2.2 mg/l; 25% saturated) where the second highest ammonia-nitrogen concentrations was measured. The high ammonia-nitrogen concentrations observed at Site 4 could be due to a one-time, localized event that occurred at the time of sampling. Because single sampling events quantify only the concentration at the exact moment that sampling occurs, this concentration may not be indicative of the true base flow ammonia-nitrogen concentration present in Curtis Creek.

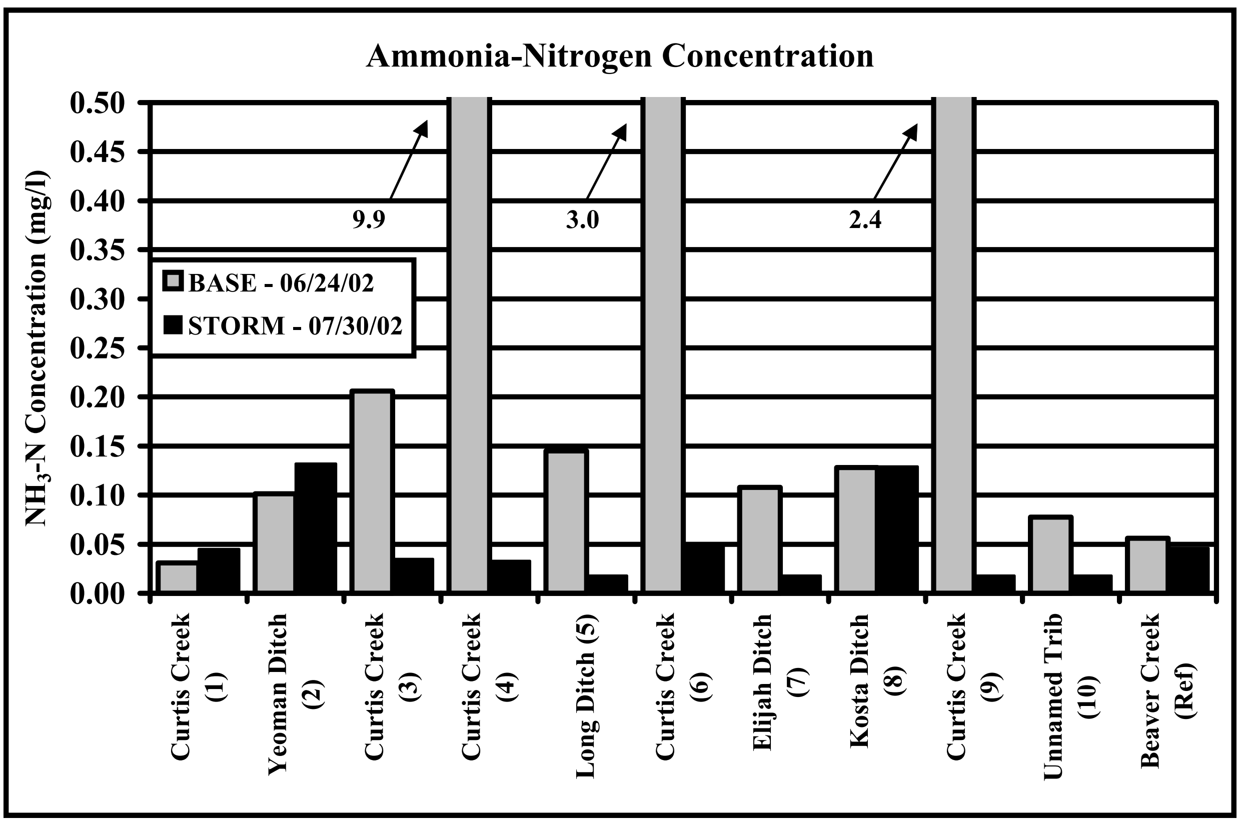


FIGURE 47. Ammonia-nitrogen concentration measurements during base flow and storm flow sampling of Curtis Creek Watershed streams.

Total Kjeldahl nitrogen (TKN) concentrations measured in streams were elevated during storm flows (Figure 48). Storm flow concentrations ranged from 0.349 mg/l at the Unnamed Tributary (Site 10) to 1.843 mg/l at the Curtis Creek Mouth (Site 1), while base flow concentrations ranged from 0.328 mg/l in Elijah Ditch (Site 5) to 14.193 mg/l in Curtis Creek at SR 114 (Site 4). Generally, TKN concentrations measured during storm flow exceeded the concentrations measured in base flow samples. The base flow samples collected in Curtis Creek at SR 114 (Site 4), CR 100 South (Site 6), and the Headwaters (Site 9) possessed the highest TKN concentrations. High TKN concentrations suggest the presence of organic matter.

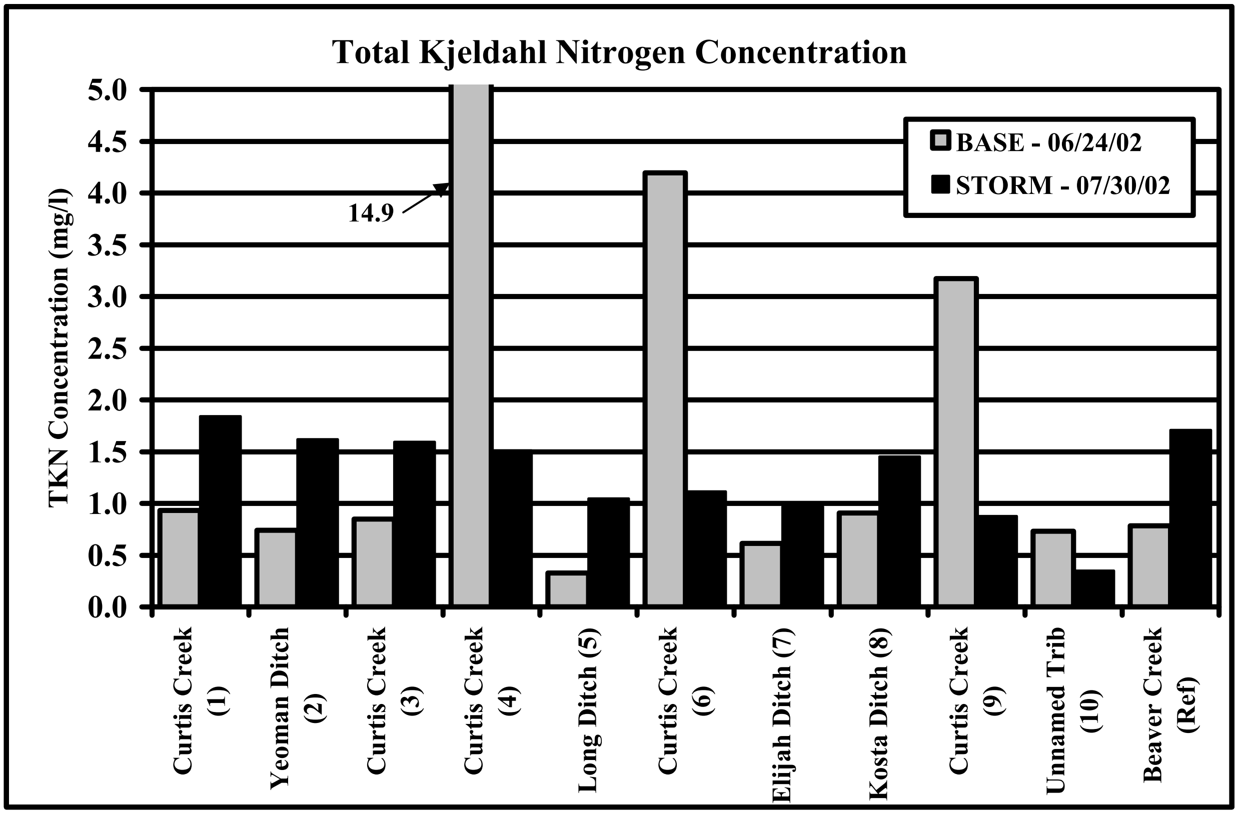


FIGURE 48. Total Kjeldahl nitrogen (TKN) concentration measurements during base flow and storm flow sampling of Curtis Creek Watershed streams.

Nearly all of the base and storm flow sample soluble reactive phosphorus (SRP) concentrations exceeded minimum levels (0.005 mg/l) that prevent overproductivity in aquatic systems (Figure 49). Storm flow SRP concentrations in Yeoman Ditch (Site 2) and Long Ditch (Site 5) and base flow concentrations in Curtis Creek Headwaters (Site 9) were elevated relative to the samples collected at other sites. Samples from most subwatersheds revealed that the soluble phosphorus fraction was <50% of the total phosphorus (TP) suggesting that most phosphorus loading was particulate or soil associated (Figure 50). However, SRP was >60% of TP at Long Ditch (Site 5) and Curtis Creek Headwaters (Site 9). Elevated particulate phosphorus levels in streams following storm events is indicative of soil loss via erosion since particulate phosphorus is typically adsorbed to soil particles.

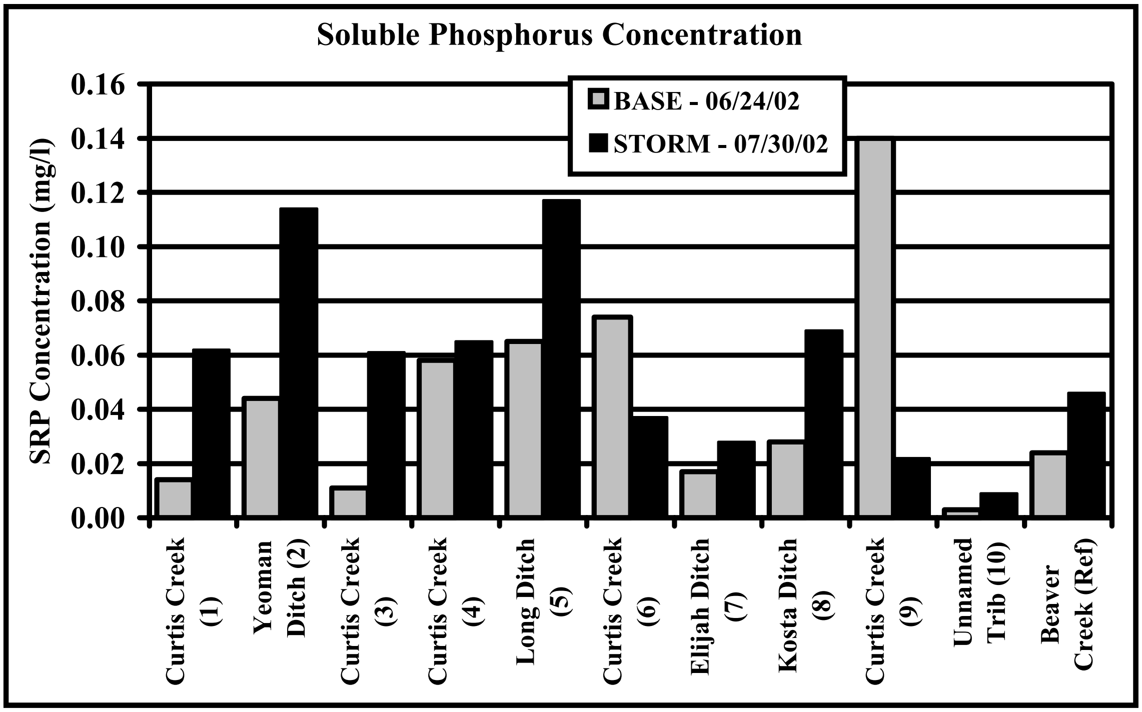


FIGURE 49. Soluble reactive phosphorus (SRP) concentration measurements during base flow and storm flow sampling of Curtis Creek Watershed streams.

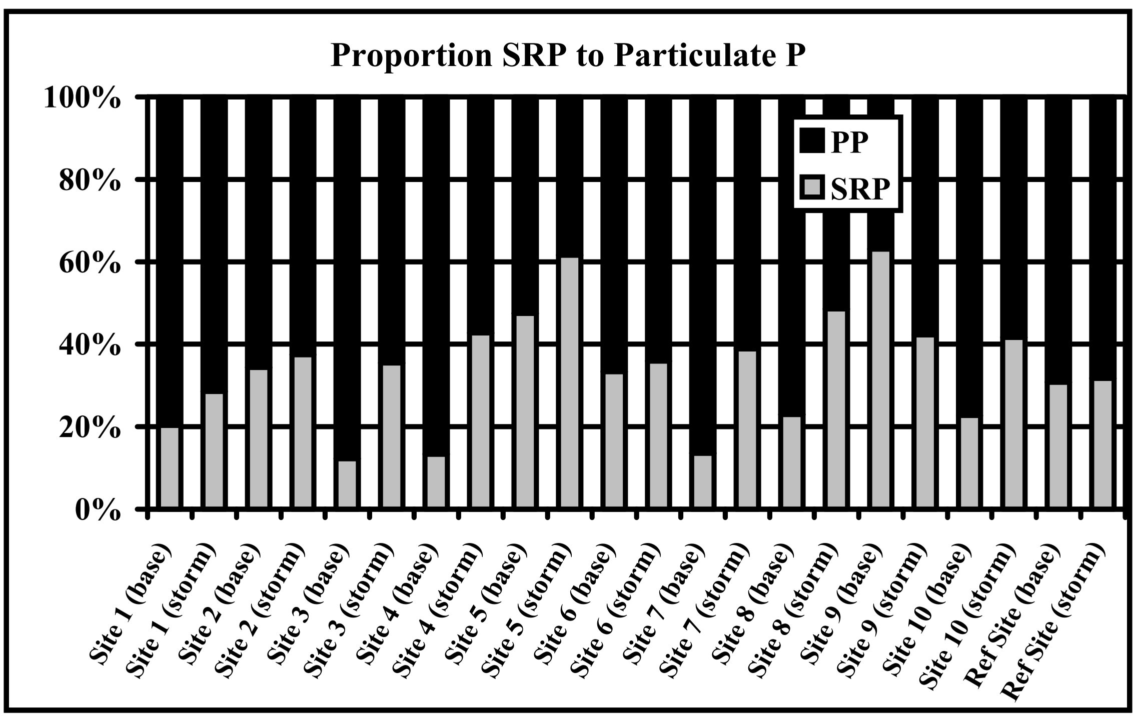


FIGURE 50. Soluble reactive phosphorus (SRP) percentage of particulate phosphorus (PP) concentration measurements during base flow and storm flow sampling of Curtis Creek Watershed streams. TP concentration minus SRP concentration yields an estimation of particulate phosphorus (PP).

Total phosphorus (TP) concentrations were notably elevated at all sites (Figure 51) especially in Curtis Creek at SR 114 (Site 4) during base flow and Yeoman Ditch (Site 2) during storm flow. TP concentrations in Curtis Creek at State Road 114 (Site 4) and Yeoman Ditch (Site 2) exceeded the median level (0.28 mg/l) measured in streams classified as modified warmwater habitat (Ohio EPA, 1999). The Ohio EPA uses this level (0.28 mg/l) as the maximum total phosphorus concentration to avoid impairment of aquatic life in modified warmwater habitat streams. Levels of total phosphorus above this standard may impair aquatic life.

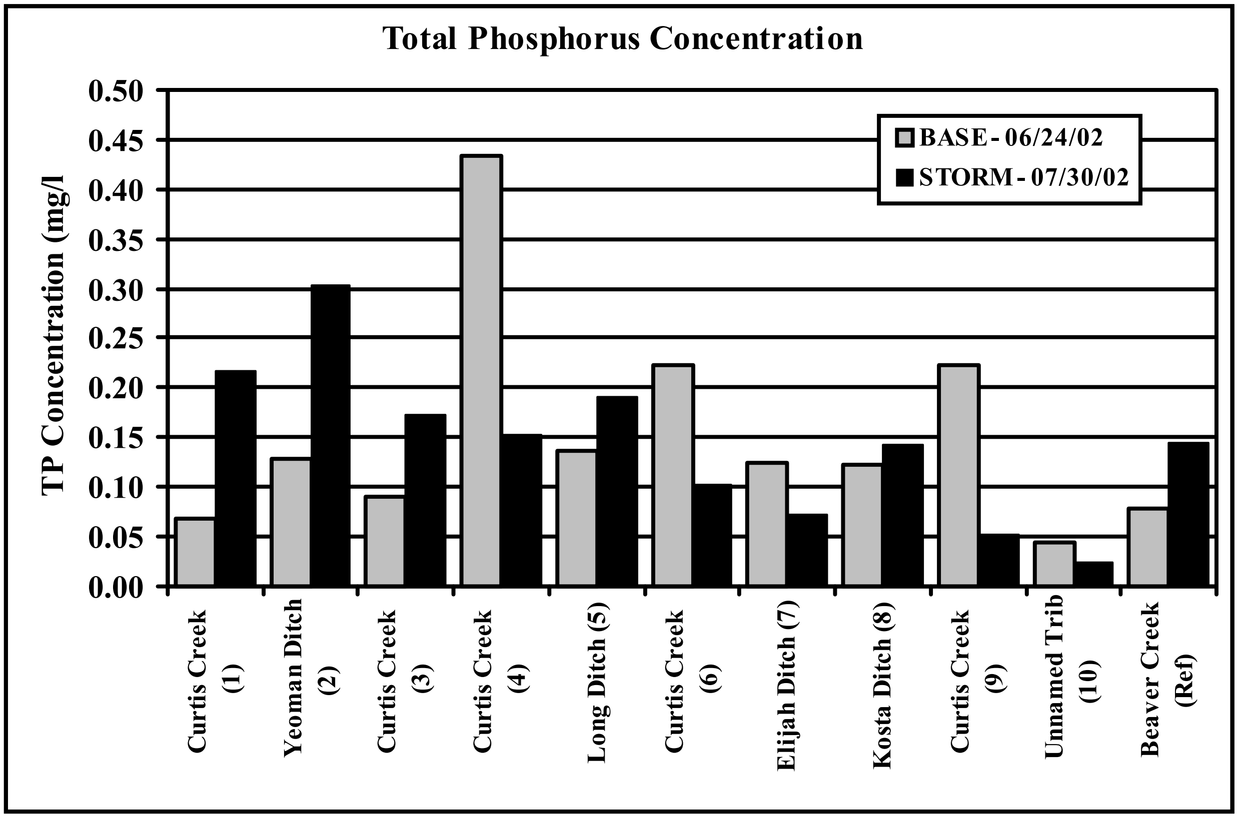


FIGURE 51. Total phosphorus (TP) concentration measurements during base flow and storm flow sampling of Curtis Creek Watershed streams.

In general, total suspended solids (TSS) concentrations were greater during storm flow conditions than during base flow conditions (Figure 52). As noted in the total phosphorus discussion, higher overland flow velocities typically result in the increase in sediment particles in runoff. Greater streambank and stream bed erosion occurs during high flow as well. Therefore, higher concentrations of suspended solids are typically measured in storm flow samples. Storm flow TSS concentration at the Mouth of Curtis Creek (Site 1) exceeded 80 mg/l, the level found to be deleterious to aquatic life (Waters, 1995).

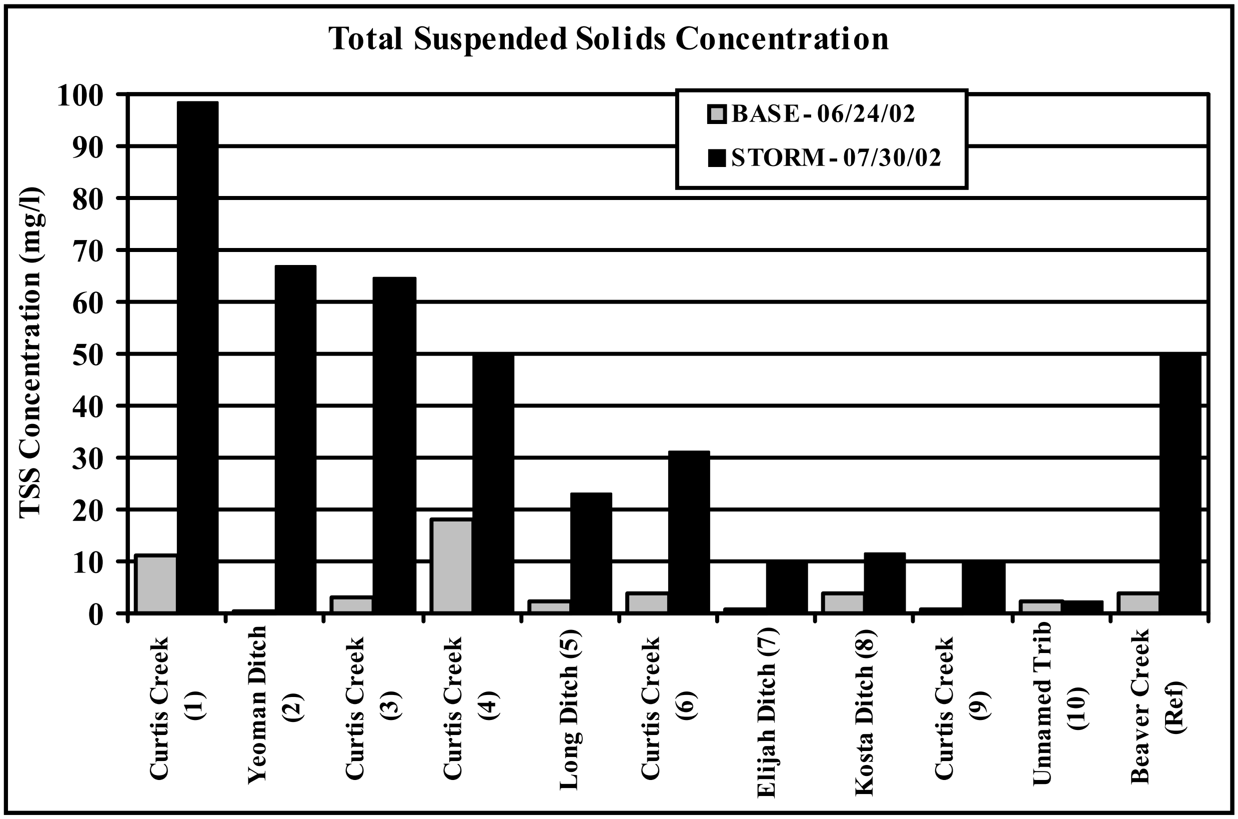


FIGURE 52. Total suspended solid (TSS) concentration measurements during base flow and storm flow sampling of Curtis Creek Watershed streams.

The Unnamed Tributary (Site 10) base flow sample was the only sample that did not exceed the Indiana state standard for *E. coli* (235 col/100 ml; Figure 53). Base flow concentrations in violation ranged from 260 at in Curtis Creek at CR 100 South (Site 6) to 3400 col/100 ml at Kosta Ditch (Site 8), while storm flow *E. coli* concentrations ranged from 420 col/100 ml in Curtis Creek Headwaters (Site 9) to 12,000 col/100ml in Long Ditch (Site 5). The high E. coli concentrations may be impairing aquatic life in these streams and may also be limiting the recreational potential of these streams.

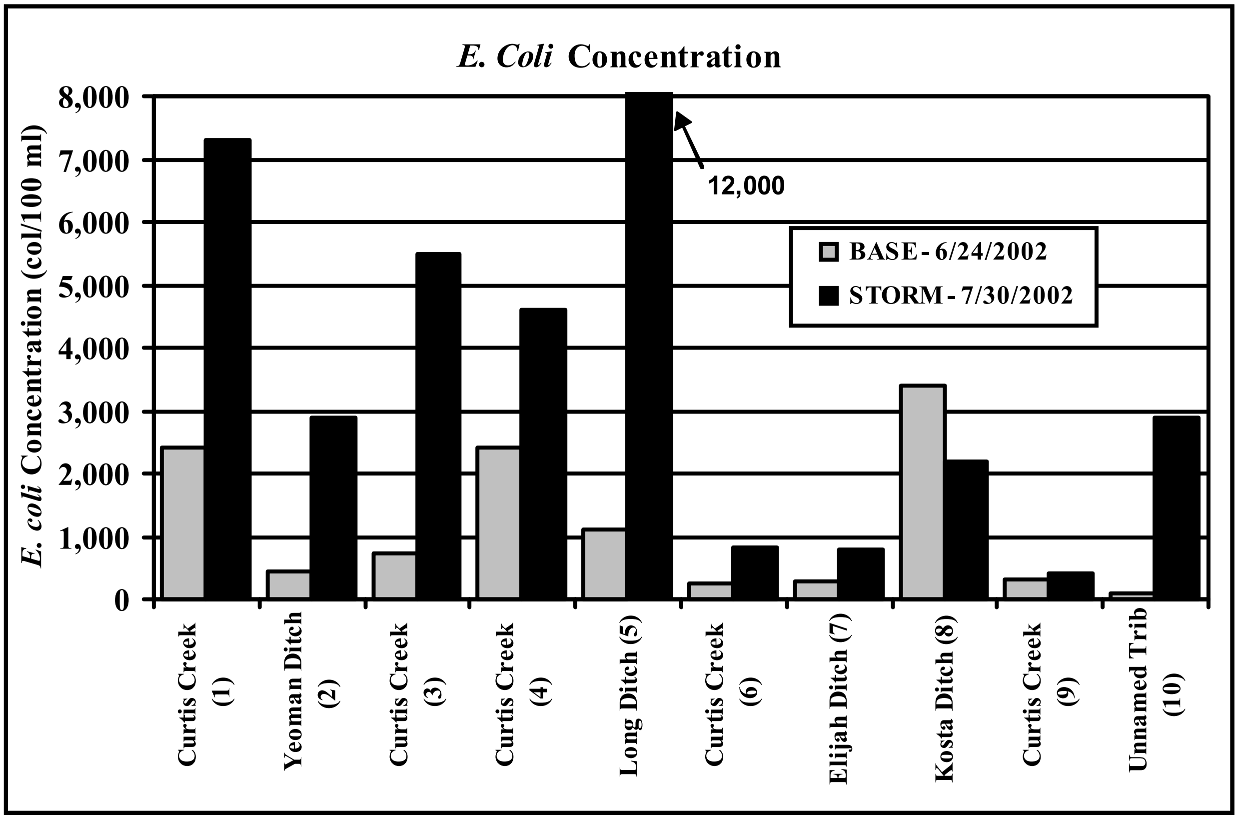


FIGURE 53. *E. coli* bacteria concentration measurements during base and storm flow sampling of Curtis Creek Watershed streams.

E. coli samples were collected from the Mouth of Curtis Creek (Site 1), Curtis Creek Headwaters (Site 9), and the Reference Site (Beaver Creek at County Road 600 West) following 0.6 inches of rainfall on March 26, 2003. All three samples contained *E. coli* concentrations below the Indiana state standard (235 colonies/100 ml; Figure 54). Cold air and water temperatures are likely inhibiting *E. coli* growth in both streams. The sources of *E. coli* Curtis Creek and Beaver Creek have not been identified; however, wildlife, livestock, and/or domestic animal defecation; manure fertilizers; previously contaminated sediments; and failing or improperly sited septic systems are common sources of the bacteria.

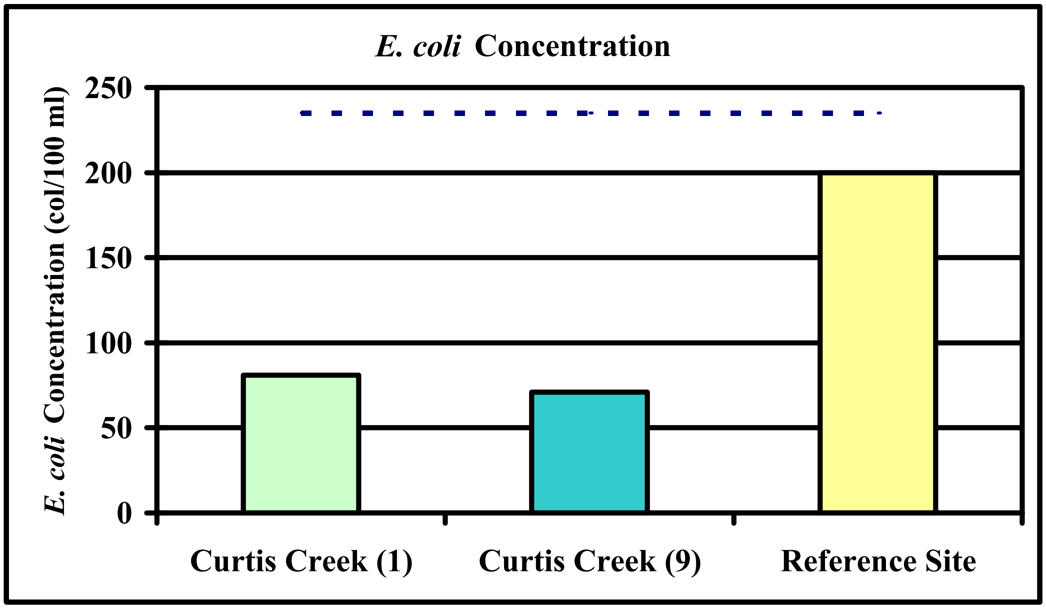


FIGURE 54. *E. coli* bacteria concentration measurements during the storm flow sampling of Curtis Creek and Beaver Creek conducted March 26, 2003. The dashed line indicates the Indiana state *E. coli* standard for grab samples (235 colonies/100 ml).

Sediment and Chemical Loading

Table 69 lists the chemical and sediment mass loading data for Curtis Creek Watershed by site. Figures 55-60 present mass loading information graphically.

TABLE 69. Chemical and bacterial loading data for watershed streams. Storm discharge could not be measured at Site 3; therefore, loading could not be calculated for this site.

Site	Date	Timing	NO_3^--N Load (kg/d)	NH_3-N Load (kg/d)	TKN Load (kg/d)	SRP Load (kg/d)	TP Load (kg/d)	TSS Load (kg/d)	*E. coli* Load (bil col/d)
1	6/24/02	Base	15.8	0.5	49.7	1.2	0.2	187.1	408
	7/30/02	Storm	611.0	14.9	2,234.6	71.9	20.6	32,624.3	24,186
2	6/24/02	Base	6.5	0.9	46.6	1.1	0.4	2.2	39
	7/30/02	Storm	23.8	1.9	91.5	4.5	1.7	980.7	426
3	6/24/02	Base	12.9	3.1	46.0	1.4	0.2	47.9	111
	7/30/02	Storm	482.9	10.6	2,019.1	52.1	18.5	19,554.1	16,662
4	6/24/02	Base	92.4	64.5	12.1	2.8	0.4	117.2	156
	7/30/02	Storm	--	--	--	--	--	--	--
5	6/24/02	Base	1.1	0.5	32.5	0.4	0.2	7.3	36
	7/30/02	Storm	13.3	0.2	104.5	2.4	1.5	292.6	1,526
6	6/24/02	Base	37.5	27.0	15.4	2.0	0.7	33.5	23
	7/30/02	Storm	102.9	4.4	455.7	9.5	3.4	2,859.6	765
7	6/24/02	Base	1.8	0.3	3.5	0.4	0.1	2.2	8
	7/30/02	Storm	2.6	0.0	19.2	0.2	0.1	26.9	21
8	6/24/02	Base	4.3	0.6	15.2	0.6	0.1	18.6	163
	7/30/02	Storm	21.0	1.9	51.8	2.0	1.0	167.5	318
9	6/24/02	Base	18.6	14.2	8.8	1.3	0.8	4.4	19
	7/30/02	Storm	32.2	0.7	120.4	1.9	0.8	357.9	154
10	6/24/02	Base	2.4	0.3	28.2	0.1	0.0	7.4	3
	7/30/02	Storm	5.3	0.3	216.5	0.4	0.1	33.4	440
Ref	6/24/02	Base	6.0	0.4	23.7	0.6	0.2	29.3	NA
	7/30/02	Storm	315.0	8.5	1,604.8	26.7	8.5	9,212.4	NA

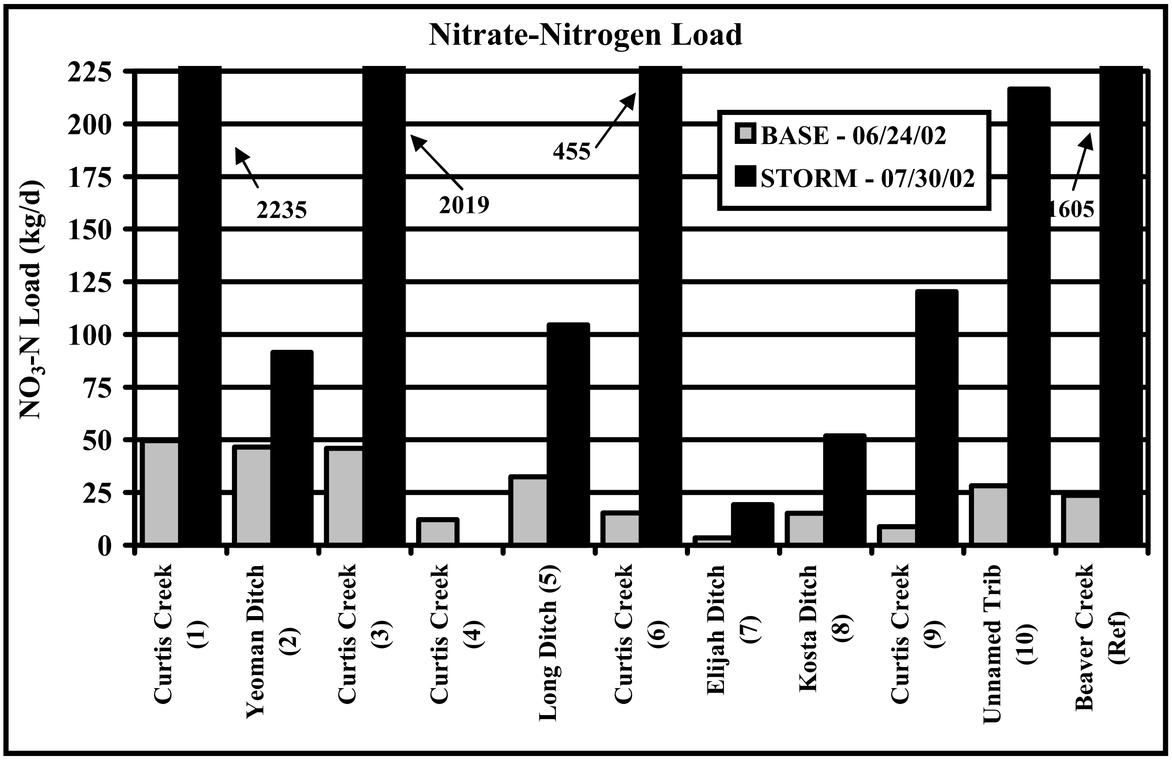


FIGURE 55. Nitrate-nitrogen loading rates during base flow and storm flow sampling of Curtis Creek Watershed streams.

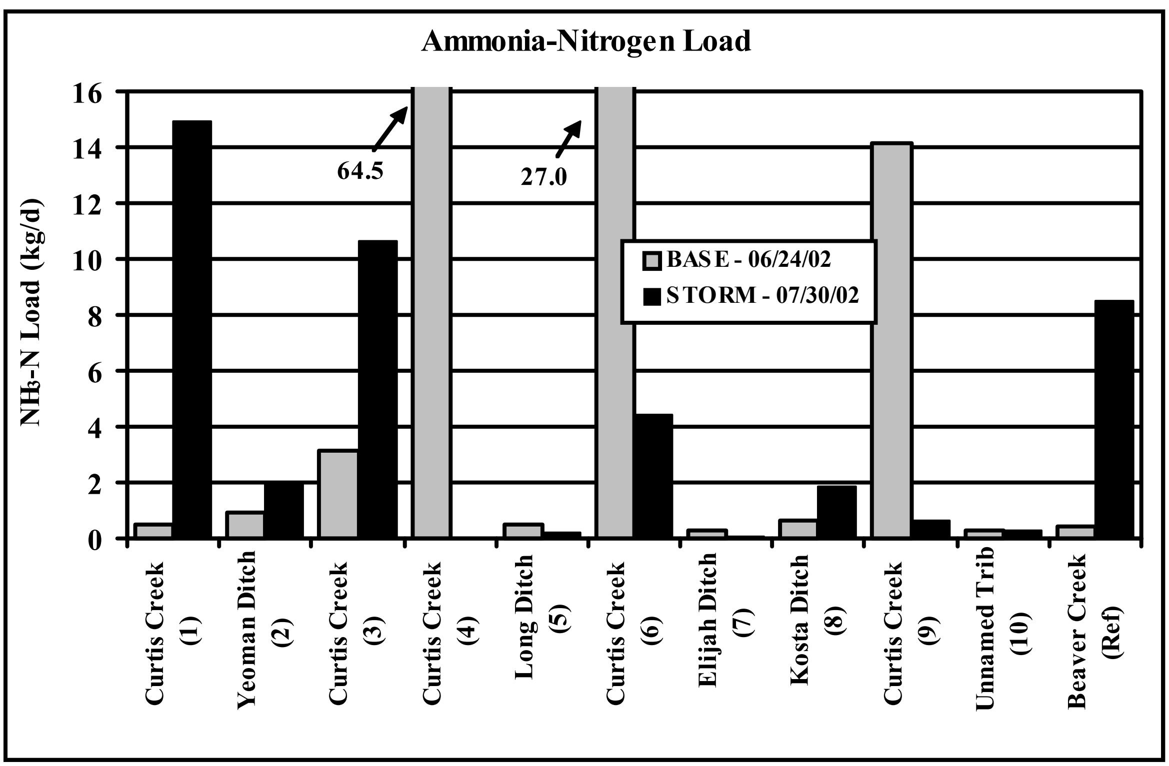


FIGURE 56. Ammonia loading rates during base flow and storm flow sampling of Curtis Creek Watershed streams.

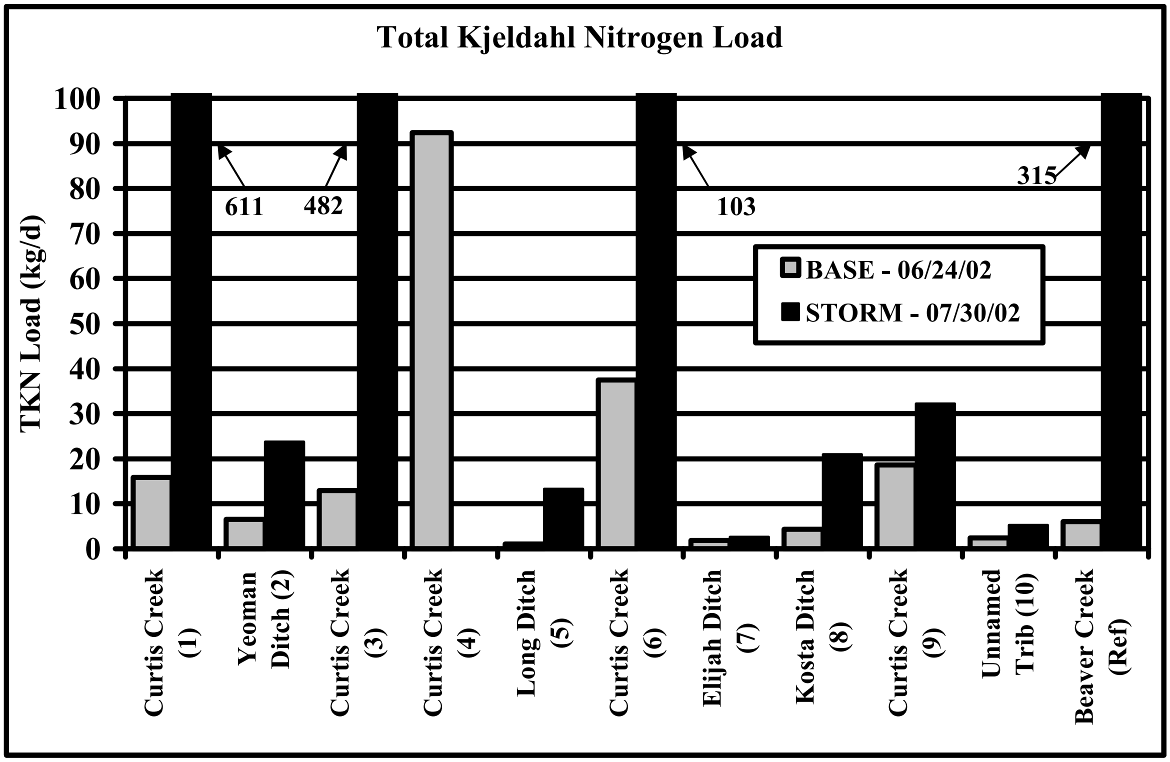


FIGURE 57. Total Kjeldahl nitrogen (TKN) loading rates during base flow and storm flow sampling of Curtis Creek Watershed streams.

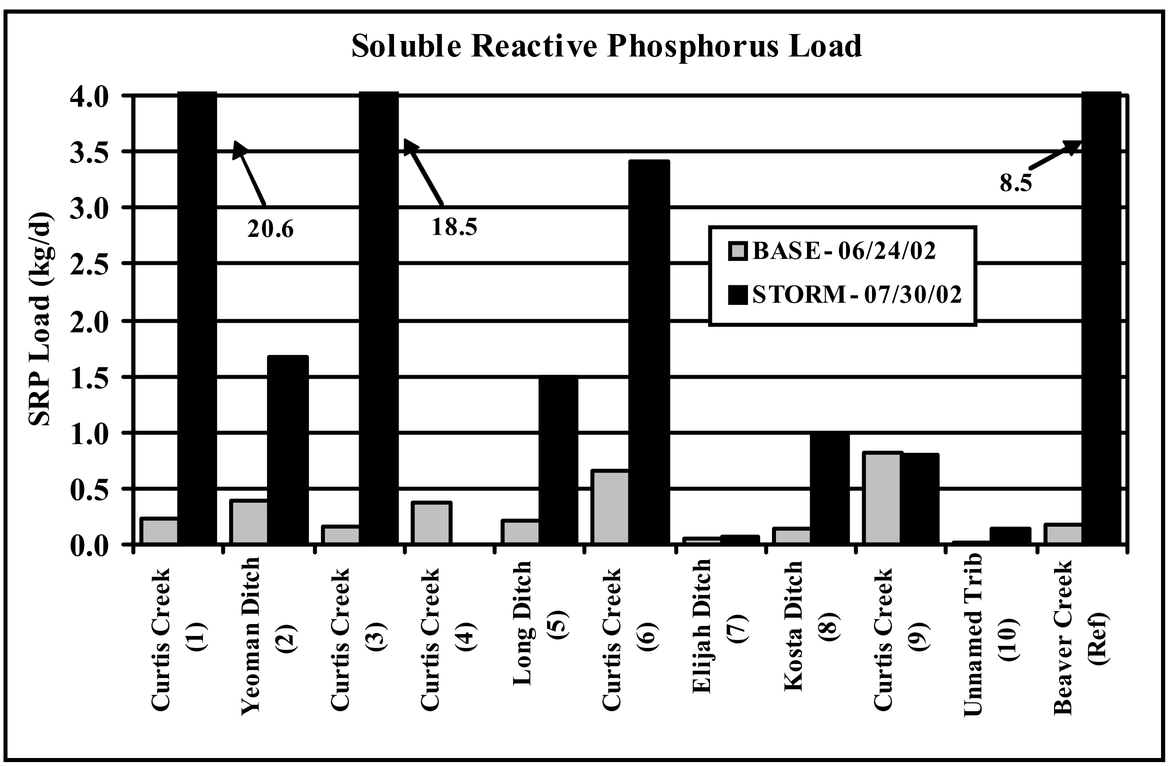


FIGURE 58. Soluble reactive phosphorus (SRP) loading rates during base flow and storm flow sampling of Curtis Creek Watershed streams.

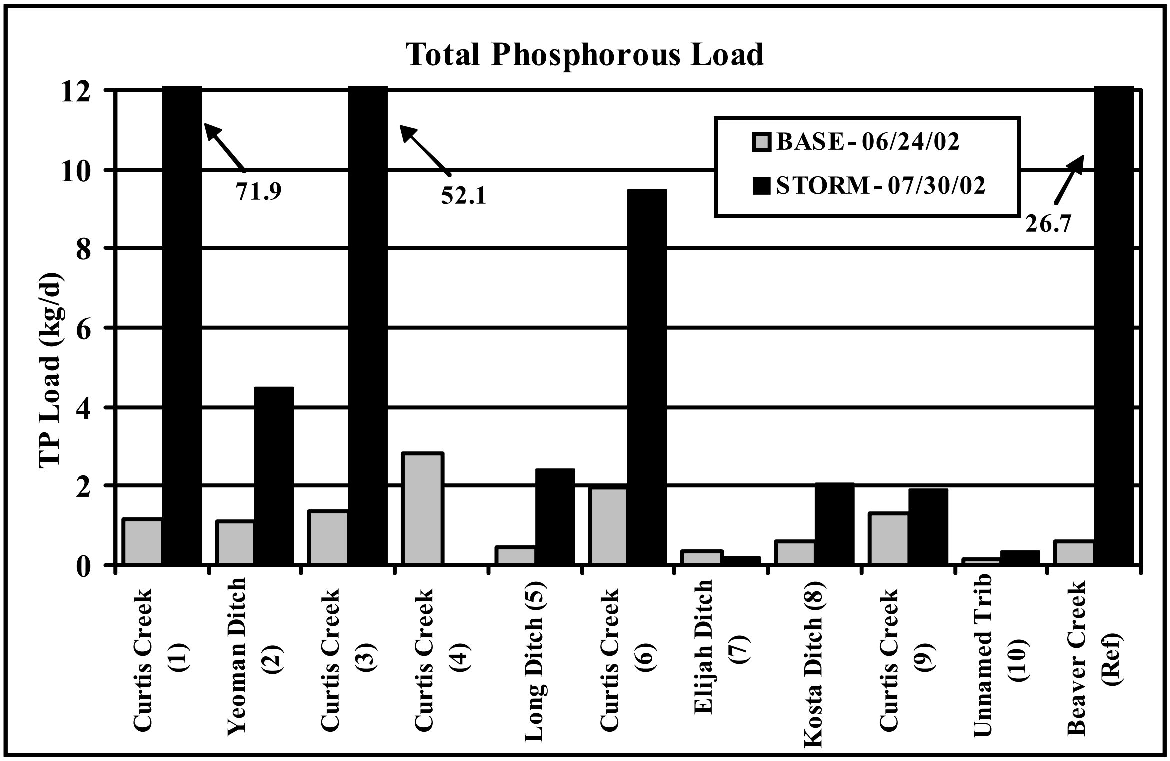


FIGURE 59. Total phosphorus (TP) loading rates during base flow and storm flow sampling of Curtis Creek Watershed streams.

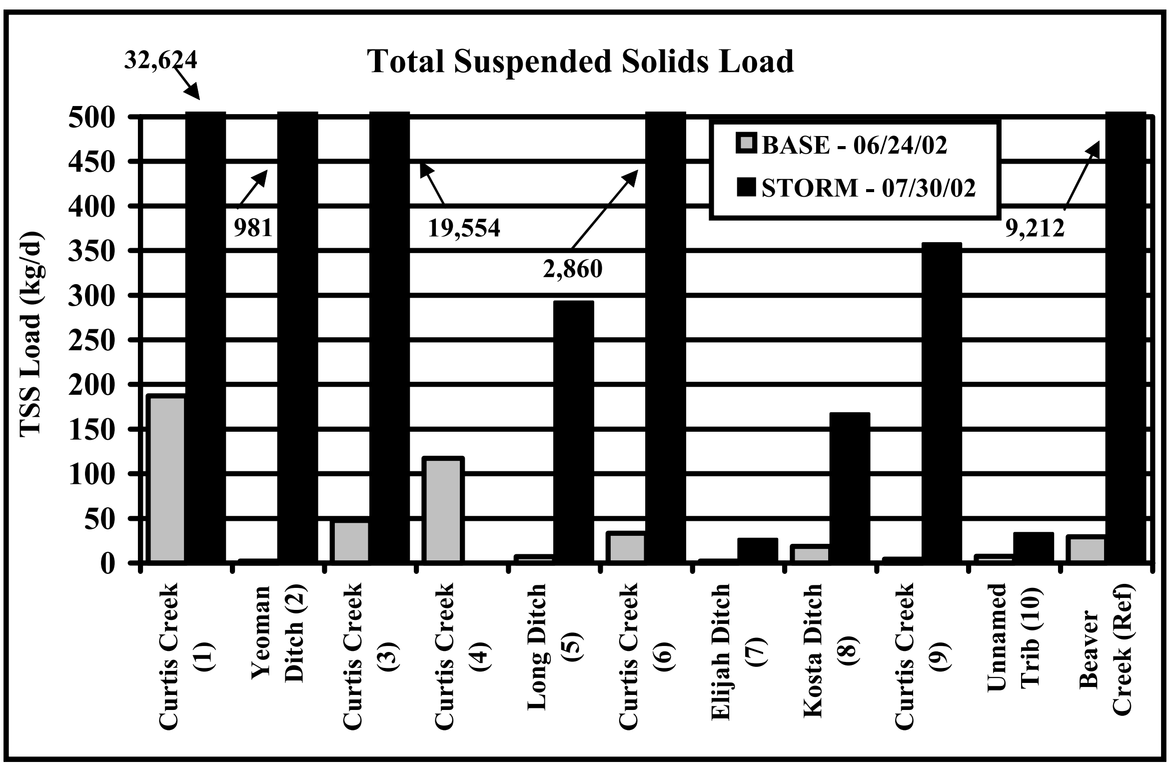


FIGURE 60. Total suspended solids (TSS) loading rates during base flow and storm flow sampling of Curtis Creek Watershed streams.

Under storm flow conditions, Curtis Creek at the Mouth (Site 1) possessed the greatest nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, soluble reactive phosphorus, total phosphorus, and total suspended solids loads. This is to be expected; since the site is located furthest downstream, it receives pollutants from all other sites. Likewise, Curtis Creek at the Mouth (Site 1) possessed the highest loads of nitrate-nitrogen and total suspended solids during base flow. In contrast, Curtis Creek at SR 114 (Site 4) possessed the greatest load of total Kjeldahl nitrogen, ammonia-nitrogen, and total phosphorus during base flow. The decrease in TKN and TP loads observed at the Golf Course site (Site 3) suggests that deposition occurs between SR 114 and the Mouth of Curtis Creek during base flow conditions.

Nutrient and sediment loading rates in the Curtis Creek Watershed streams were generally governed by flow rate (i.e. streams with higher rates of flow also contributed higher nutrient and sediment loads). Table 70 summarizes sampling locations that loaded disproportionate amounts for the various pollutants relative to discharge rate (i.e., these streams loaded more nutrients and/or sediment despite having smaller discharges than other streams where data was collected). Nitrate-nitrogen loading was disproportionate for Long Ditch (Site 5) and the Unnamed Tributary (Site 10) during storm flow and Yeoman Ditch (Site 2), Curtis Creek Golf Course (Site 3), Long Ditch (Site 5), and the Unnamed Tributary (Site 10) during base flow (Figure 55). Ammonia-nitrogen loading was governed by flow during storm conditions. Curtis Creek at SR 114 (Site 4), at CR 100 S (Site 6), and at the Headwaters (Site 9) possessed disproportionate ammonia-nitrogen loading rates during base flow (Figure 56). Curtis Creek at CR 100 S (Site 6), Yeoman Ditch (Site 2) and Kosta Ditch (Site 8) during storm flow and Curtis Creek at SR 114 (Site 4), at CR 100 S (Site 6), and Headwaters (Site 9) during base flow exhibited high TKN loading rates (Figure 57). Phosphorus loading rates were the parameter least dependent on flow rate (Figures 58 and 59). SRP and TP loading rates were disproportional to flow rate during storm flow at Yeoman Ditch (Site 2), Long Ditch (Site 5), and Kosta Ditch (Site 8) and during base flow for Yeoman Ditch (Site 2) and Curtis Creek at the Headwaters (Site 9). Additionally, Curtis Creek at SR 114 (Site 4) and at CR 100 S (Site 6) possessed disproportionate loading rates for TP during base flow. Yeoman Ditch (Site 2) during storm flow and Kosta Ditch (Site 8) and Curtis Creek Mouth (Site 1) Subwatersheds during base flow carried larger amounts of suspended solids relative to discharge, suggesting that these subwatershed areas had detectibly higher sediment loss rates (Figure 60). Sediment loading rates were variable but high at some sites ranging from 2.2 to 32,624 kg/d (4.8 to 71,924 lbs/d) depending on flow regime and location.

TABLE 70. Streams that loaded disproportionate amount to the various parameters relative to discharge rate.

Site	Parameter	Event
Yeoman Ditch (Site 2)	NO_3-N	Base
Curtis Creek Golf Course (Site 3)	NO_3-N	Base
Long Ditch (Site 5)	NO_3-N	Base and Storm
Unnamed Tributary (Site 10)	NO_3-N	Base and Storm
Curtis Creek at SR 114 (Site 4)	NH_3-N	Base
Curtis Creek at CR 100 S (Site 6)	NH_3-N	Base
Kosta Ditch (Site 8)	NH_3-N	Storm
Curtis Creek Headwaters (Site 9)	NH_3-N	Base
Yeoman Ditch (Site 2)	TKN	Storm
Curtis Creek at SR 114 (Site 4)	TKN	Base
Curtis Creek at CR 100 S (Site 6)	TKN	Base and Storm
Kosta Ditch (Site 8)	TKN	Storm
Curtis Creek Headwaters (Site 9)	TKN	Base
Yeoman Ditch (Site 2)	SRP	Base and Storm
Long Ditch (Site 5)	SRP	Storm
Curtis Creek Headwaters (Site 9)	SRP	Base
Yeoman Ditch (Site 2)	TP	Base and Storm
Curtis Creek at SR 114 (Site 4)	TP	Base
Long Ditch (Site 5)	TP	Base and Storm
Curtis Creek at CR 100 S (Site 6)	TP	Base
Kosta Ditch (Site 8)	TP	Storm
Curtis Creek Headwaters (Site 9)	TP	Base
Curtis Creek Mouth (Site 1)	TSS	Base
Yeoman Ditch (Site 2)	TSS	Storm
Curtis Creek at SR 114 (Site 4)	TSS	Base

Water Chemistry Summary

In general, physical and chemical parameter data collected from streams in the Curtis Creek Watershed suggest that these streams at least suffer from at least moderate levels of water quality degradation. Nutrient concentrations were generally higher than nutrient concentrations standards used modified Ohio streams to protect aquatic life. (Indiana does not have numeric nutrient criteria for the protection of aquatic life.) Similarly, bacteria concentrations were high during both base and storm runoff conditions. Only one bacteria sample collected possessed an *E. coli* concentration below the state standard. Additionally, bacteria levels were high when compared to other agricultural watersheds in Indiana. Sediment loading rates varied but were quite high at some sites ranging from 2.2 to 32,624 kg/day (4.8 to 71,924 lb/day) depending on flow conditions and location. While some reaches acted as sinks for sediment, phosphorus, and bacteria, others exhibited high loading rates for pollutants, particularly during high water stage.

The Mouth Subwatershed possessed higher nutrient, sediment, and bacteria loading rates than any other subwatershed during both base and storm conditions (Table 69). The Golf Course Subwatershed also possessed high nutrient, sediment, and bacteria loading rates during base and storm flow. In summary, the stream sampling data suggests that Yeoman Ditch, Long Ditch, Curtis Creek at CR 100 S, and Lower Curtis Creek (Golf Course and Mouth) are more impaired than the other waterbodies or sites in the Curtis Creek Watershed.

Macroinvertebrates and Habitat

Macroinvertebrate Sampling Methods

Data from macroinvertebrate sampling at each of the 10 sites in the Curtis Creek Watershed and the reference site were used to calculate an index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The macroinvertebrate community composition reflects water quality. Research shows that different macroinvertebrate orders and families react differently to pollution sources. Thus, indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995)

Macroinvertebrates were collected during base flow conditions on June 24, 2002 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al. 1999). This method was supplemented by qualitative picks from the substrate and by surface netting. Two researchers collected macroinvertebrates for 20 minutes and a third researcher aided in the collection for 10 minutes for a total of 50 minutes of collection effort. The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the same manual. Organisms were identified to the family level. The family-level approach was used because: 1) it would allow data collected in this study to be compared to that collected by the Indiana Department of Environmental Management (IDEM); 2) it allows for increased organism identification accuracy; 3) several studies support the adequacy of family-level analysis (Furse et al., 1984; Ferraro and Cole, 1995; Marchant, 1995; Bowman and Bailey, 1997; Waite et al., 2000).

Macroinvertebrate data were used to calculate the family-level Hilsenhoff Biotic Index (HBI). Calculation of the HBI involves applying assigned macroinvertebrate family tolerance values to all taxa present that have an assigned HBI tolerance value, multiplying the number of organisms present by their family tolerance value, summing the products, and dividing by the total number of organisms present (Hilsenhoff, 1988). A higher HBI value indicates greater impairment.

In addition to the HBI, macroinvertebrate results were analyzed using a modified version of IDEM's modified Index of Biotic Integrity (mIBI) (IDEM, unpublished). mIBI scores allow comparison with data compiled by IDEM for wadeable streams. IDEM developed the classification criteria based on five years of wadeable data collected in Indiana. The data were lognormally distributed for each of the metrics. Each metric's lognormal distribution was then pentasected with scoring based on five categories using 1.5 times the interquartile range around the geometric mean. Table 71 lists the eight scoring metrics used in this study with classification scores of 0-8. The mean of the eight metrics is the mIBI score. mIBI scores of 0-2 indicate the sampling site is severely impaired; scores of 2-4 indicate the site is moderately impaired; scores of 4-6 indicate the site is slightly impaired; and scores of 6-8 indicate that the site is non-impaired.

TABLE 71. Benthic macroinvertebrate scoring criteria used by IDEM in the evaluation of streams in Indiana.

	SCORING CRITERIA FOR THE FAMILY LEVEL MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY (mIBI) USING PENTASECTION AND CENTRAL TENDENCY ON THE LOGARITHMIC TRANSFORMED DATA DISTRIBUTIONS OF THE 1990-1995 RIFFLE KICK SAMPLES				
	CLASSIFICATION SCORE				
	0	2	4	6	8
Family Level HBI	>5.63	5.62- 5.06	5.05-4.55	4.54-4.09	<4.08
Number of Taxa	<7	8-10	11-14	15-17	>18
Percent Dominant Taxa	>61.6	61.5-43.9	43.8-31.2	31.1-22.2	<22.1
EPT Index	<2	3	4-5	6-7	>8
EPT Count	<19	20-42	43-91	92-194	>195
EPT Count To Total Number of Individuals	<0.13	0.14-0.29	0.30-0.46	0.47-0.68	>0.69
EPT Count To Chironomid Count	<0.88	0.89-2.55	2.56-5.70	5.71-11.65	>11.66
Chironomid Count	>147	146-55	54-20	19-7	<6

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Nonimpaired

Habitat Sampling Methods

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates; amount and quality of instream cover; channel morphology; extent and quality of riparian vegetation; pool, run, and riffle development and quality; and gradient are some of the metrics used to determine the QHEI score which generally ranges from 20 to 100.

Substrate type(s) and quality are important factors of habitat quality and the QHEI score is partially based on these characteristics. Sites that have greater substrate diversity receive higher scores as they can provide greater habitat diversity for benthic organisms. The quality of substrate refers to the embeddedness of the benthic zone. Small particles of soil and organic matter can settle into small pores and crevices in the stream bottom. Many organisms can colonize these microhabitats, but high levels of silt in a streambed can result in the loss of habitat within the substrate. Thus, sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

In-stream cover, another metric of the QHEI, represents the type(s) and quantity of habitat provided within the stream itself. Examples of in-stream cover include woody logs and debris, aquatic and overhanging vegetation and root wads extending from the stream banks. The channel morphology metric evaluates the stream's physical development with respect to habitat diversity. Pool and riffle development within the stream reach, the channel sinuosity, and other factors that represent the stability and direct modification of the site are evaluated to comprise this metric score.

A wooded riparian buffer is a vital functional component of riverine ecosystems. It is instrumental in the detention, removal, and assimilation of nutrients. According to the Ohio EPA (1999), riparian zones govern the quality of goods and services provided by riverine ecosystems. Riparian zone and bank erosion were examined at each site to evaluate the quality of the buffer zone of a stream, the land use within the floodplain that affects inputs to the waterway, and the extent of bank erosion, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian buffer is a zone that is forest, shrub, swamp, or woody old field vegetation. Typically, weedy, herbaceous vegetation does not offer as much infiltration potential as woody components and does not represent an acceptable riparian zone type for the QHEI (Ohio EPA, 1989).

The fifth QHEI metric evaluates the quality of pool/glide and riffle/run habitats in the stream. When present, these zones provide diverse habitat structure which, in turn, can increase habitat quality and availability. The depth of pools within a reach and the stability of riffle substrate are some factors that affect the QHEI score in this metric.

The final QHEI metric evaluates the topographic gradient in a stream reach. This is calculated using topographic data. The score for this metric is based on the premise that both very low and very high stream gradients will have negative effects on habitat quality. Moderate gradients receive the highest score, 10, for this metric.

The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1995).

Macroinvertebrate and Habitat Results

mIBI and QHEI scores for each sampling site are given in Tables 72 and 73. Detailed mIBI and QHEI results are included in Appendix 7 and 8, respectively. The mIBI scores ranged from 2.25 to 5.25. All QHEI scores except Beaver Creek (Reference Site; 68) fell below 60, the level conducive to existence of warmwater faunas (Ohio EPA, 1999). Figure 61 shows cross-sections of the stream sampling sites. Nearly all of the sites have relatively steep banks, indicative of stream modification and channelization. Following the tables is a site-by-site description of particular characteristics that contribute to the mIBI and QHEI scores at each site.

TABLE 72. Metric classification scores and mIBI score for the Curtis Creek Watershed sampling sites as sampled June 24-25, 2002.

Site	HBI	No. Taxa (family)	% Dominant Taxa	EPT Index	EPT Count	EPT Count/ Total Count	EPT Abun./ Chir. Abun.	Chironomid Count	mIBI Score
Curtis Creek Mouth (1)	4	8	8	4	2	2	4	6	**4.75**
Yeoman Ditch (2)	0	8	8	0	0	0	0	6	**2.75**
Curtis Creek Golf Course (3)	2	8	8	6	2	2	6	8	**5.25**
Curtis Creek SR 114 (4)	0	8	8	0	0	0	2	6	**3.00**
Long Ditch (5)	2	6	6	0	0	0	0	4	**2.25**
Curtis Creek CR 100 S (6)	6	8	6	0	0	0	2	8	**3.75**
Elijah Ditch (7)	0	8	6	0	0	0	0	4	**2.25**
Kosta Ditch (8)	4	8	6	2	0	0	0	4	**3.00**
Curtis Creek Headwaters (9)	0	6	6	0	0	0	2	6	**2.5**
Unnamed Tributary (10)	0	8	4	0	0	0	2	4	**2.25**
Beaver Creek (Ref)	6	8	2	6	4	8	6	8	**6**

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Nonimpaired

TABLE 73. QHEI scores for the Curtis Creek Watershed sampling sites as sampled June 24-25, 2002.

Site	Substrate Score	Cover Score	Channel Score	Riparian Score	Pool Score	Riffle Score	Gradient Score	Total Score
Maximum Possible Score	20	20	20	10	12	8	10	**100**
Curtis Creek Mouth (1)	6	3	9.5	7	6	2	8	**42**
Yeoman Ditch (2)	8	6	12	5	0	0	6	**37**
Curtis Creek Golf Course (3)	6	7	7	4	10	3	6	**43**
Curtis Creek at SR 114 (4)	2	9	5	5	7	2	8	**38**
Long Ditch (5)	8	7	10	7	5	3	2	**42**
Curtis Creek at CR 100 S (6)	8	4	5	4	0	0	6	**27**
Elijah Ditch (7)	9	10	8	5	0	0	4	**36**
Kosta Ditch (8)	8	7	7	4	4	2	4	**36**
Curtis Creek Headwaters (9)	8	7	7	4	6	4	6	**42**
Unnamed Tributary (10)	8	3	4	4	0	0	4	**23**
Beaver Creek (Reference Site)	17	8	14	9	10	6	4	**68**

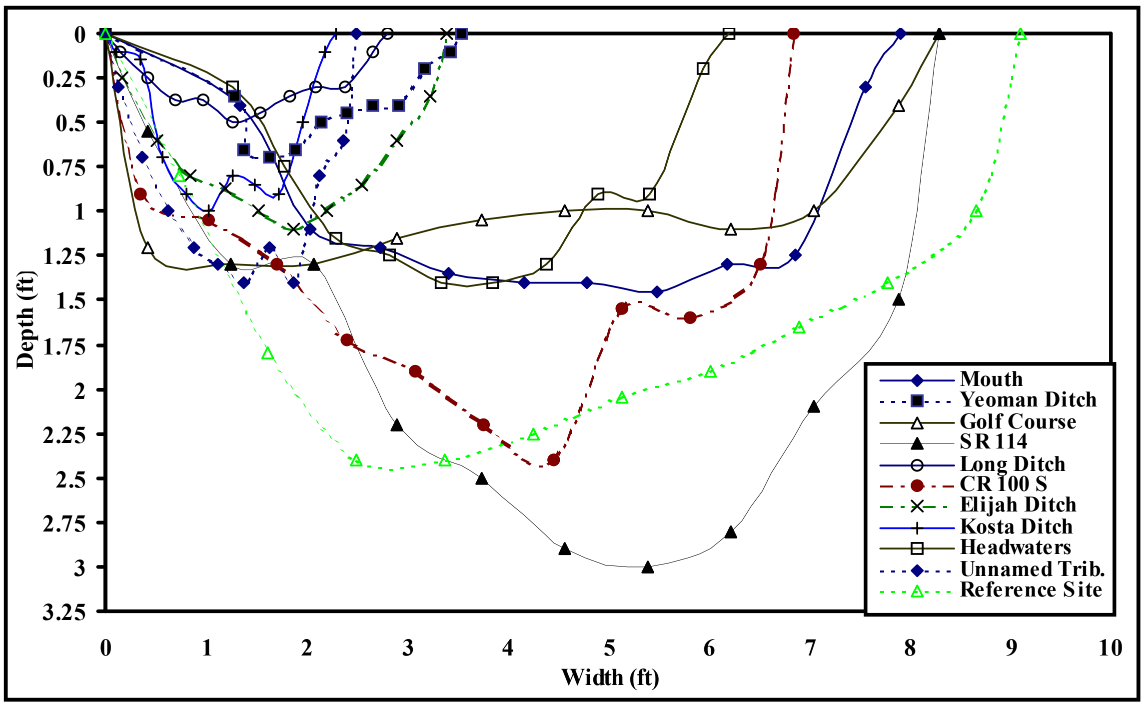


FIGURE 61. Cross-sections of Curtis Creek Watershed streams at sampling locations.

Site 1 – Mouth of Curtis Creek. The QHEI score at this site was 42 of 100 total possible points, the second highest of any of the study streams. The substrate was 95% sand and 5% silt. Substrate embeddedness was extensive; heavy silt cover was also present. In-stream conditions were poor with low substrate stability and poor riffle and pool development. Second growth trees dominated the riparian vegetation. The trees provided both canopy and in-stream cover in the form of root wads, logs, and woody debris (Figure 62). The creek at this site had one of the widest stream channels of any in the study area (8.3 feet; Figure 61). The mIBI score for the site was 4.75, the second highest of any of the Curtis Creek sites. The highly intolerant *Platyhelminthes* taxon *Planaria* was the dominant taxon sampled at this site. However, moderately tolerant taxa from the taxon *Diptera* composed a large portion of the "slightly" impaired macroinvertebrate community. This indicates the water and habitat quality were relatively unimpaired within this reach of Curtis Creek compared to other study reaches.

FIGURE 62. Site 1 sampling location on Curtis Creek.

Site 2 – Yeoman Ditch. The lack of a riparian buffer and limited pool and riffle development characterized the habitat quality at this site (Figure 63). The channel had moderate sinuosity with fairly well developed channel morphology. The channel cross section showed that the stream was fairly shallow (less than 0.75 feet) for its width (3.55 feet) relative to other sites in the Curtis Creek Watershed. The substrate was predominantly sand (80%) with some cobble, gravel, and silt. The QHEI score of 37 reflects the relatively poor habitat quality of this site. The mIBI score of 2.75 is also indicative of the impaired conditions present in Yeoman Ditch. The *Dipteran* family *Chironomidae* and the *Hemipteran* family *Notonectidae*, both highly tolerant taxa, dominated the macroinvertebrate community.

FIGURE 63. Site 2 sampling location on Yeoman Ditch.

Site 3 – Curtis Creek Golf Course. This site received the highest QHEI score of any of the Curtis Creek sites, 43 of 100 total possible points. Sand dominated the substrate at this site; gravel, cobble, and silt were also present. Root wads, undercut banks, and woody debris provided in-stream cover (Figure 64). Young trees and grasses dominated the riparian vegetation. Riffle development and sinuosity were non-existent indicating little or no recovery from past modification. The mIBI score was the highest (5.25) of any of the sites representing a "slightly" impaired system. The *Hemipteran Gerridae* dominated the macroinvertebrate community. This taxon is relatively intolerant to habitat and water quality degradation indicating a healthier community compared to the communities at other study sites. The presence of other similarly intolerant macroinvertebrates, like individuals of the *Ephemeroptera* and *Trichoptera* orders, contributed to the higher mIBI score.

FIGURE 64. Site 3 sampling location on Curtis Creek.

Site 4 – Curtis Creek at State Road 114. This site received a QHEI score of 38 out of a possible 100. The extensive embeddedness and poor substrate composition of sand and muck resulted in the worst substrate score of the study receiving only 2 of the possible 20 points. Bank erosion was evident along the stream channel, which was straight and channelized. Grasses and shrubs vegetated the narrow riparian zone (Figure 65). Large woody debris, aquatic macrophytes, overhanging vegetation, and root wads provided in-stream habitat. The stream cross-section showed that the stream was the widest (8.3 feet) and deepest (3 feet) of any of the sampling sites (Figure 61). The mIBI score of 3.0 reflected slightly better habitat and water quality relative to other sites. The *Hemipteran* family *Notonectidae* dominated the "moderately" impaired system. The presence of relatively intolerant taxa and high community diversity elevated the score compared to other study sites.

FIGURE 65. Site 4 sampling location on Curtis Creek.

Site 5 - Long Ditch. The QHEI score for this site was 42, the second highest score assessed during the study. Sand, gravel, and silt composed the channel substrate. Trees and grasses dominated the riparian zone vegetation. Overhanging vegetation, root wads, aquatic macrophytes, and woody debris provided habitat diversity within the stream (Figure 66). The mIBI score (2.25) was indicative of an impaired macroinvertebrate community. The tolerant *Dipteran* family *Chironomidae* dominated the insect community. The absence of individuals from the *Ephemeroptera*, *Plecoptera*, and *Trichoptera* orders lowered the score suggests that anthropogenic disturbance has limited water and habitat quality at this site.

FIGURE 66. Site 5 sampling location on Long Ditch.

Site 6 – Curtis Creek at County Road 100 South. Channelization and limited pool and riffle development characterized the habitat at this site. The creek at this site lacked any resemblance to a natural waterway in that it was very straight and showed no recent recovery from channelization. Curtis Creek at this site also received poor pool quality scores (Figure 67). There was no riffle formation observed at the site. This stream's cross-section showed that the stream was fairly deep (2.5 feet) for its width (6.9 feet; Figure 61) compared to other study sites. The riparian zone was comprised of grasses with little or no shrubby or woody vegetation. Some aquatic macrophyte growth within the stream channel provided limited in-stream cover. The substrate was predominately sand with some gravel and fine particulate organic matter (FPOM) or muck. The site's QHEI score of 27, the second lowest, reflects the relatively poor habitat quality of this site. The mIBI score of 3.75 is also an indicator of impaired conditions. Although a good diversity of organisms was collected, a lack of intolerant taxa characterized the macroinvertebrate community.

FIGURE 67. Site 6 sampling location on Curtis Creek.

Site 7 – Elijah Ditch. The QHEI score for this reach was 36 out of a possible 100. Sand dominated the substrate; FPOM and silt were also present within the reach. Narrow riparian buffers vegetated with grasses and shrubs bordered the adjacent agricultural field (Figure 68). Woody debris, overhanging vegetation, and aquatic macrophytes provided moderate habitat diversity in the stream. No pool or riffle development was present within the reach further detracting from the QHEI score. The mIBI score for the site was 2.25, reflecting a "moderately" impaired community. Although the site supports a large diversity of macroinvertebrate taxa, the dominant families, *Chironomidae*, the *Gastropod Physidae*, and the *Coleopteran Psephenidae*, are all moderately tolerant. The low EPT metric scores reduced the overall score due.

FIGURE 68. Site 7 sampling location on Elijah Ditch.

Site 8 – Kosta Ditch. Small trees and shrubs directly bordered Kosta Ditch providing moderate canopy cover (Figure 69). Although the riparian zone was comprised of woody vegetation, this zone was very narrow and provided little buffering from the adjacent agricultural fields. Over hanging vegetation, shallows, aquatic macrophytes, and woody debris provided in-stream habitat diversity. Even though canopy and in-stream cover were readily available, the QHEI score of 36 indicated that other habitat characteristics were of poor quality. Heavy siltation was evident and the substrate was predominantly sand. Riffles and pools, though present, were poorly developed. The mIBI score for the site was 3.0 indicating "moderate" impairment. The score was influenced by the dominance of relatively tolerant taxa such as *Chironomidae* and the absence of EPT taxa.

FIGURE 69. Site 8 sampling location on Kosta Ditch.

Site 9 – Curtis Creek at the Headwaters. Site 9 also received the second highest QHEI score of the study (42). Substrate composition was 35% sand, 25% gravel, 25% silt, and 15% cobble. The channel lacked sinuosity, showing no recovery from historical channelization at this site (Figure 70). The creek channel was buffered by a narrow riparian zone vegetated with young trees and shrubs. Aquatic macrophytes, woody debris, and overhanging vegetation provided in-stream cover. Pools and riffles were poorly developed. The mIBI score was 2.5, an indication of "moderate" impairment. The very tolerant bivalve *Sphaeriidae* dominated the macroinvertebrate community. Although moderate diversity of organisms was collected a lack of intolerant taxa and the absence of individuals from the orders *Ephemeroptera*, *Plecoptera*, and *Trichoptera* lowered the overall score.

FIGURE 70. Site 9 sampling location on Curtis Creek.

Site 10 – Unnamed Tributary. The QHEI score for this site was 23, the lowest score of the study. The substrate was comprised of 95% sand and 5% silt and was moderately imbedded. The site was directly adjacent to agricultural fields, but possessed a narrow, grassy riparian zone (Figure 71). Some aquatic vegetation was observed within the channel, but otherwise the channel had no signs of habitat cover or canopy shading. The ditch's wetted width was approximately 2.5 feet and the depth in the channel was 1.5 feet with no pool or riffle development. The channel banks are steep and greater than 6 feet high. The mIBI score (2.25) was also the lowest of any of the sites. The tolerant families *Chironomidae* and *Physidae* dominated the macroinvertebrate sample, which lowered the HBI metric of the mIBI score. The under-representation of individuals from the orders *Ephemeroptera*, *Plecoptera*, and *Trichoptera*, which are expected to comprise larger portions in healthier communities, also reduced the overall score.

FIGURE 71. Site 10 sampling location on the Unnamed Tributary.

Reference Site – Beaver Creek. This site received the highest QHEI score, 68 of a possible 100. Substrate composition consisted of 40% gravel, 30% cobble, and 20% sand and boulder. Normal siltation and moderate embeddedness was evident throughout the reach. In-stream cover was extensive resulting in the highest score for the cover metric of the QHEI (Figure 72). Channel development was good, and the channel was moderate stabile. A wide, forested riparian zone bordered the stream and no stream bank erosion was present. In-stream vegetation, root wads, overhanging vegetation, and deep pools provided additional habitat diversity. Riffles and pools were moderately well developed throughout the site. The mIBI score was the highest of any site. The score of 6.0 classified the site as non-impaired. The dominant macroinvertebrates were relatively intolerant taxa; the *Trichopteran Hydropsychidae* and the *Ephemeropteran Heptageniidae*, were the most prevalent macroinvertebrate taxa. The presence of *Hydropsychidae*, an EPT taxon, benefited the mIBI score; however, their rather high dominance (51%) did detract from the score. This is as expected because a more evenly distributed community is expected in a healthy system.

FIGURE 72. Reference site sampling location on Beaver Creek.

Macroinvertebrate and Habitat Discussion

The overall evaluation of biotic health and habitat quality in the Curtis Creek Watershed indicates that these waterways are slightly to moderately degraded. Many of the study sites lacked at least one of the key elements of natural, healthy stream habitats. These missing key elements limit the functionality of these systems. The QHEI evaluations from each site describe poor substrate quality throughout streams in the Curtis Creek Watershed. Additionally, QHEI scores reflected the poor pool and riffle development in watershed streams. These factors are critical for habitat diversity and biological integrity in the stream ecosystems. In the Curtis Creek Watershed moderate to poor mIBI scores reflected the degraded habitat condition.

Heavy sediment loading was an apparent factor in the degradation of substrate quality in the study streams. Several sites along the mainstem of Curtis Creek and in Yeoman Ditch and Kosta Ditch have experienced significant levels of siltation. Extensive substrate embeddedness severely limits habitat diversity within the stream channel by filling in and closing off porous areas that offer refuge for a variety of aquatic organisms. This heavy sediment loading is reflected in the poor substrate scores of the QHEI evaluations. The range of substrate scores was 1 to 9 out of a possible 20.

Channel alterations such as ditching, dredging, straightening, and other modifications also affect stream habitat diversity. Altering the natural stream morphology (shape) impacts riffle and pool development, resulting in less diverse habitat for macroinvertebrate and fish colonization. As reflected in the QHEI evaluations and cross-sections, many of the study reaches have been impacted by channelization. Steep stream banks and straight reaches indicate that these streams have been modified and lack natural sinuosity and development.

Another important aspect of good habitat quality that is conspicuously missing from many of the study sites is an effective riparian zone to buffer stream systems from the surrounding land use. Stable, woody vegetation zones that naturally form adjacent to streams and other waterways provide distinct functions that enhance habitat quality (Ohio EPA, 1999). Primarily, this zone slows run off, collects sediment, and stores nutrients that would otherwise be loaded into the stream system. Poor QHEI and mIBI scores are also probably related to riparian zone absence. Site 1 on Curtis Creek and the Reference Site on Beaver Creek benefit from healthy riparian zones and also support a healthy macroinvertebrate community. Extensive woody vegetation around streams provides additional habitat in the form of logs and woody debris, overhanging vegetation, and submerged root wads. Riparian vegetation also provides canopy cover that shades the stream and minimizes thermal inputs. Shade can also limit extensive, nuisance levels of aquatic vegetation that are dependent upon sufficient levels of solar radiation. Unfiltered nutrient-rich runoff can also promote vegetation and algal growth. Mowed grassy vegetation adjacent to streams does little to slow runoff flows into the stream and therefore is less capable of trapping sediments and nutrients. Based on observations made during sampling events, the quality and quantity of riparian zone vegetation is moderately to severely limited throughout the watershed.

Each of these physical factors contributes to habitat quality, and their absence or degradation at most of the sites is related to the macroinvertebrate community structure. Overall, the mIBI scores were rather low with the exception of Curtis Creek at the Mouth (Site 1) and Golf Course (Site 3). Site 3 received the highest QHEI and mIBI scores, suggesting that habitat factors do have an impact on the quality of ecological communities. The other eight sites received mIBI scores indicating varying degrees of “moderate” impairment. In a healthy stream system, a community of both tolerant and intolerant taxa is expected. Impacts of degradation will tend to limit or eliminate organisms that are incapable of persisting in such systems. In general, tolerant taxa dominated the Curtis Creek Watershed samples leading to lower mIBI scores.

It is important to remember that overall watershed condition will impact habitat and biotic quality. In fact, scientific data suggest that watershed condition may have a greater influence on macroinvertebrate measures than local riparian land use (Weigel et al., 2000). So although local streamside best management practices are important, a broader, watershed-level approach is necessary to effectively address biotic integrity and stream health. An additional study by Osmond and Gale (1995) showed that large-scale reductions in agricultural non-point source pollution are necessary for stream health improvement. An example of working at a watershed level includes coordinating with producers to implement nutrient, pesticide, tillage, and coordinated resource management plans.

Macroinvertebrate and Habitat Summary

Because many of the stream reaches surveyed had been channelized in the past, many natural stream characteristics were absent or severely deficient as indicated by the low QHEI scores. The overall habitat degradation components that impair conditions for aquatic life within the Curtis Creek Watershed were:

- Poor pool-riffle development: Deep places (pools) and shallow places (riffles) within a stream reach offer habitat variety for aquatic organisms and can impact certain chemical characteristics of flowing water like temperature, dissolved oxygen concentrations, and suspended sediment load.
- Siltation/substrate embeddedness: Excessive loading of fine sediments and silt clogs or embeds the substrate spaces destroying habitat for aquatic invertebrates and fish.
- Channel alterations: Ditching, dredging, straightening, and other changes to channel structure can affect the ability of organisms to live in the stream.
- Poor in-stream cover: In-stream cover like undercut banks, overhanging vegetation, woody debris, and aquatic vegetation offer protection and habitat for aquatic organisms. Like pools and riffles, in-stream cover can also affect certain chemical characteristics like temperature and dissolved oxygen.
- Lack of or very narrow riparian zone: Farming and other land use practices very near or even at the stream's edge decrease canopy cover over the stream increasing thermal pollution in the stream and decrease the potential for woody debris (cover) in the stream. Additionally, narrow riparian areas do not filter or infiltrate runoff as efficiently as filter areas that are at least 30 feet wide (NRCS, 2000).

These habitat characteristics are important for the aquatic life in the streams. As one would expect, the impaired habitat conditions in the study streams were reflected in mIBI scores. In general, at sites with poorer habitat fostered poorer macroinvertebrate communities. These communities exhibited a higher tolerance to pollution and lower diversity. All QHEI scores fell below 60, the level that has been found to be conducive to aquatic life, and mIBI scores ranged from "moderately" impaired to "slightly" impaired.

Relationships Among Chemical, Biological, and Habitat Characteristics

Chemical parameters and biological and habitat indices were analyzed for relationships that could provide additional insight into mechanisms governing impairment within the subwatersheds. The following list includes parameters for which no statistically significant linear relationship was found:

- QHEI score vs. HBI
- QHEI score vs. TSS (mg/l)
- QHEI score vs. Flow (cfs)
- QHEI score vs. Turbidity (NTU)
- QHEI score vs. TSS (mg/l)
- QHEI vs. mIBI
- mIBI vs. NH_3 (mg/l)
- mIBI vs. SRP (mg/l)
- mIBI vs. TP (mg/l)
- mIBI vs. TSS (mg/l)
- mIBI vs. DO (mg/l)
- mIBI vs. NO_3 (mg/l)
- mIBI vs. TKN (mg/l)
- QHEI Substrate vs. mIBI
- QHEI Cover vs. mIBI
- QHEI Riparian vs. mIBI
- QHEI Riffle vs. mIBI
- QHEI Substrate vs. Turbidity (mg/l)
- QHEI Substrate vs. TSS (mg/l)

One explanation for this lack of correlation is that these creeks are, in general, highly modified, somewhat artificial drainage ditches, and consequently might not reflect natural relationships among parameters of water quality, habitat condition, and biological health. In many cases, the response variable shows such a limited range (due to being highly modified) that a correlation is impossible.

Two positive correlations were found among physical and habitat parameters:

- Flow vs. mIBI (Figure 73)
- mIBI vs. QHEI Pool (Figure 74)

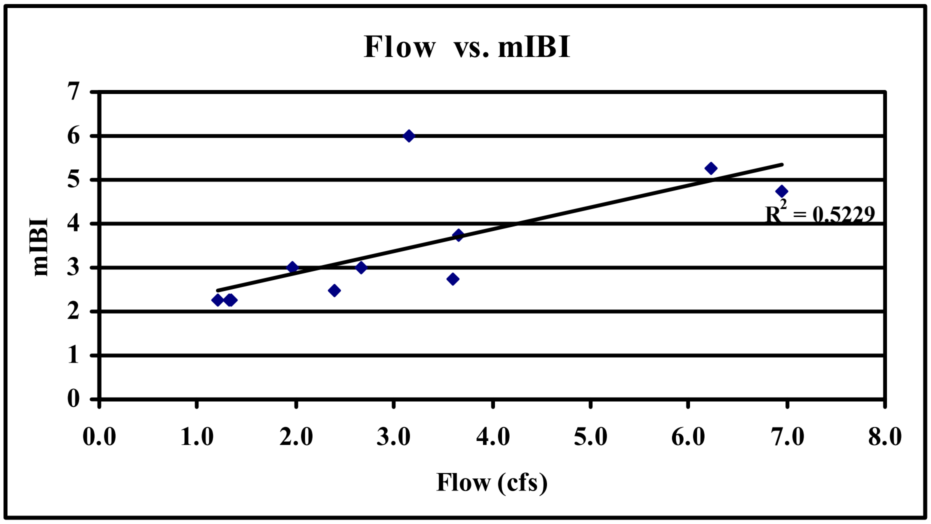


FIGURE 73. Statistically significant relationship ($p<0.005$) between mIBI score and flow for the Curtis Creek Watershed.

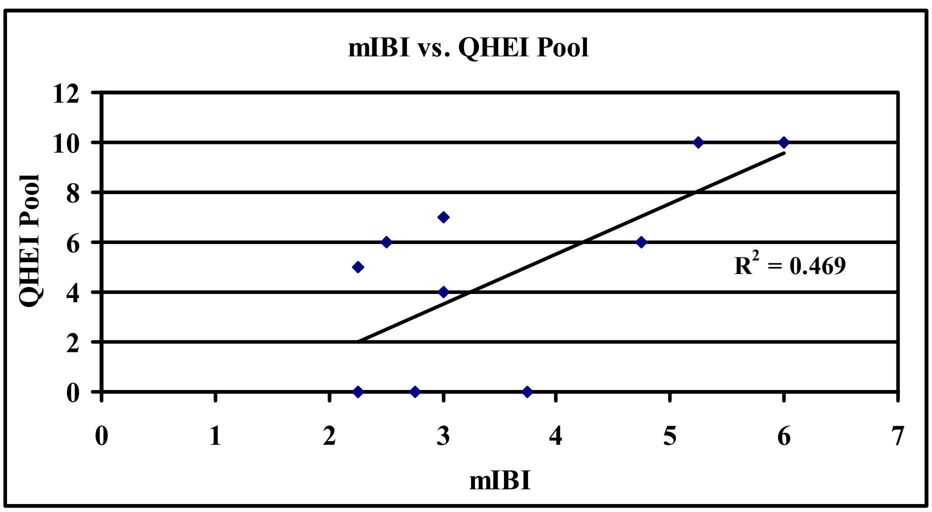


FIGURE 74. Statistically significant relationship ($p=0.09$) between mIBI score and QHEI pool score for the Curtis Creek Watershed.

This relationship illustrated between discharge and mIBI (Figure 73) is expected based on the importance of flow and stream dynamics. Flowing water brings a continuous supply of nutrients and food particles to stream biota. For example, the concentrations of dissolved organic matter (DOM) increase as a function of discharge in many streams (Allan, 1995). The concentration of particulate organic matter (POM) increases with the first flush of a storm event and then becomes diluted with additional discharge as the supply of POM is exhausted. In systems like Curtis Creek, where there is an overabundance of organic matter present in the stream and its substrate, higher discharges can mobilize and transport the POM. As Hynes (1970) stated in his classic work, current makes the water "physiologically richer" because of its constant renewal of materials in solution near the surfaces of stream organisms. Thus, low discharge streams, such as Long Ditch, Elijah Ditch, or the Unnamed Tributary, do not provide stable food sources for aquatic organisms

The relationship illustrated in Figure 74 is based on the premise that greater habitat availability as "pools" positively influences the macroinvertebrate community that inhabits these spaces. Typically in watersheds that are dominated by agricultural activity, stream channel morphology is greatly manipulated jeopardizing the integrity of the biological communities. Pool development and quality is determined by the sorting of particles in that stream reach. Pools provide deeper areas with slower velocity for various macroinvertebrates, diversifying habitat. The lack of pool development is likely associated with land use alterations and the activity of channelizing the streams into agricultural drainage ditches. Associated with these activities are increased erosion and siltation of the streambed, which then interferes with typical sorting of particles that forms both riffles and pools (Allan, 1995). This scenario explains why typical riffle-pool patterns are lacking, but does not make a strong correlation within the watershed between the morphological characteristics and biological integrity. This absent feature confirms the interaction and degradation between substrate characteristics and suspended solids. High TSS and turbidity concentrations contribute to the embeddedness characteristic of every site within the Curtis Creek watershed.

No significant correlation was found with nutrient inputs and habitat quality, even though their interactions are well understood. The Ohio EPA found that degradation of the biotic community was observable when streams median nitrate-nitrogen concentrations exceeded 3-4 mg/l (Ohio EPA 1999). The base flow nitrate concentrations of half the stream sites in this watershed exceeded 3 mg/l. (Low flow nutrient data are usually used since low flow conditions represent conditions under which aquatic fauna live most of their lives (Ohio EPA, 1999)). Higher nitrate concentrations typically foster insect communities of higher tolerance and lower diversity. A weak relationship (r^2=0.25) that supports this premise was observed in the Curtis Creek Watershed.

Total phosphorus and soluble reactive phosphorus concentrations were not statistically related to macroinvertebrate community integrity within the Curtis Creek Watershed. The Ohio EPA documented an inverse relationship between phosphorus concentrations and biological community performance in numerous streams in Ohio (Ohio EPA, 1999). Excessive soil erosion and particulate and dissolved nutrient inputs have been shown to be associated with agricultural land use and stream degradation (Allan, 1995). Unlike their well-organized, diverse, and trophically dynamic high quality aquatic counterparts, degraded aquatic systems do not sequester available nutrients. Even though higher nutrient inputs are present within the watershed, there was no significant correlation with biological and habitat integrity.

PHOSPHORUS MODELING

Since phosphorus is the limiting nutrient in most streams, watershed management programs often target phosphorus as a nutrient to control. Because of this, a phosphorus model was used to estimate the dynamics of this important nutrient in these watersheds.

The limited scope of this LARE study did not allow for the determination phosphorus inputs and outputs outright. Therefore, a standard phosphorus model was used to estimate the phosphorus budget. Reckhow et al. (1980) compiled phosphorus loss rates from various land use activities as determined by a number of different studies, and calculated phosphorus export coefficients for each land use in the watershed. Mid-range estimates of these phosphorus export coefficient values were utilized for most watershed land uses (Table 74).

TABLE 74. Phosphorus export coefficients (units are kg/hectare except the septic category, which are kg/capita-yr).

Estimate Range	Row Crops	Non-Row	Pasture	Forest	Precipitation	Urban	Septic
High	5.0	1.5	2.5	0.3	0.6	3.0	1.8
Mid	2.0	0.8	0.9	0.2	0.3	1.0	0.4-0.9
Low	1.0	0.5	0.1	0.1	0.15	0.5	0.3

Source: Reckhow et al., 1980.

Phosphorus export coefficients are expressed as kilograms of phosphorus lost per hectare of land per year. These are multiplied by the amounts of land in each of the land use category to derive an estimate of annual phosphorus export (as kg/year) for each land use per watershed (Table 75).

Because row crop agriculture is the dominant land use within each of the subwatershed units, the proportional mass of phosphorus estimated from row cropland is also high, nearly 91% of the total estimated phosphorus loss. The percentage of phosphorus loss due to row crops ranges from a low of 75% in the Fair Oaks (10) and Golf Course (3) Subwatersheds to a high of 94% in the Headwaters (9) Subwatershed. When the data are normalized for subwatershed area (Table 76), all sub-basins contribute similar amounts of phosphorus. According to the model, the Headwaters Subwatershed loaded the most phosphorus per unit area (19,930 kg/ha-yr). The model estimates that 42,581 kilograms (46.9 tons) of phosphorus is lost from lands within the project area each year. Significant reduction of phosphorus loading to local streams will necessitate additional management of agricultural sources.

TABLE 75. Results of phosphorus export modeling by subwatershed given in kg/yr.

	P-Export Coefficient[a]	Mouth (1)[b]	Yeoman (2)	Golf Course (3)	SR 114 (4)	Long (5)	CR 100 S (6)	Elijah (7)	Kosta (8)	Headwaters (9)	Fair Oaks (10)	TOTALS	% of Total
Pasture/Hay	0.9	129	377	96	576	222	293	90	73	652	461	2672	6.28%
Row Crops	2.0	988	2973	425	2477	1807	2209	731	489	6555	694	38696	90.88%
Small Grains	0.8	--	1	--	--	--	0.2	--	--	4	1	5	0.01%
Deciduous Forest	0.2	73	268	319	370	90	437	415	408	456	47	577	1.35%
Evergreen Forest	0.15	20	26	31	28	9	21	12	11	64	5	34	0.08%
Mixed Forest	0.175		--	--	0.8	--	--	--	--	--	--	0	0.00%
Grassland	0.5	16	34	16	98	30	61	33	10	105	16	210	0.49%
Emerg. Herb. Wetlands	0.1	5	12	6	4	0.4	10	8	3	2	1	5	0.01%
Woody Wetland	0.1	33	60	35	117	23	30	6	15	30	2	35	0.08%
High Intensity Commercial	1.5	--	34	0.2	--	4	--	--	20	31	13	153	0.36%
High Intensity Residential	1.9	--	4	0.02	--	0.8	--	--	--	3	--	15	0.03%
Low Intensity Residential	1.0	0.03	13	1	0.6	24	--	--	0.1	21	--	60	0.14%
Open Water	0	2	14	1	--	0.2	--	--	0.1	3	1	0	0.00%
Other Grasses (Parks)	1.0	7	2	106	0.7	4	--	--	--	--	--	120	0.28%
Bare Rock	0.1		0.2	--	--	--	--	--	--	0.2	--	0	0.00%
TOTAL	--	**2128.5**	**6441.4**	**1124.3**	**5613.1**	**3886.0**	**4806.9**	**1645.7**	**1163.9**	**13929.7**	**1841.6**	**42581.2**	**100%**

[a]From Reckhow et al., 1980.
[b]All units are kilograms phosphorus per year.

Table 76. Results of phosphorus export modeling by subwatershed given in kg/ha-yr.

Subwatershed	Phosphorus Export (kg/ha-yr)
Mouth Subwatershed (1)	4.13
Yeoman Ditch Subwatershed (2)	4.17
Golf Course Subwatershed (3)	2.68
SR 114 Subwatershed (4)	3.78
Long Ditch Subwatershed (5)	4.33
CR 100 S Subwatershed (6)	3.88
Elijah Ditch Subwatershed (7)	3.14
Kosta Ditch Subwatershed (8)	2.79
Headwaters Subwatershed (9)	4.34
Fair Oaks Subwatershed (10)	3.67

RECOMMENDATIONS

All of the subwatersheds within the Curtis Creek Watershed could benefit from land treatment and best management strategies as already described in detail in the Review of Existing Information Section. Finances, time, manpower, and other restraints make it impossible to implement all of these management techniques at once. Thus, it is necessary to prioritize the recommendations.

These prioritizations and recommendations are simply guidelines based on conditions documented during this study. These conditions may change as land use within the watershed changes. Management efforts may need to be prioritized differently based on project feasibility and individual landowner willingness to participate. To ensure maximum participation in any management effort, all watershed stakeholders should be allowed to participate in prioritizing the management efforts in the watershed.

It is also important to note that even if all stakeholders agree that this is the best prioritization to meet their needs, action need not be taken in this order. Some of the smaller, less expensive recommendations may be implemented while funds are raised to implement some of the larger projects. Many of the larger projects will require feasibility work to ensure landowner willingness to participate in the project. In some cases, it may be necessary to attain regulatory approval as well. Landowner endorsement and regulatory approval along with stakeholder input may ultimately determine the prioritization of management efforts.

Results from the mapping exercises, the aerial tour, the windshield survey, water quality sampling, biological sampling, habitat sampling, and the modeling exercise were used to prioritize subwatersheds for future work. The subwatersheds are discussed in order of priority. It is also important to note that in order to make prioritizations, it is necessary to make some generalizations. Additional general recommendations, like innovative riparian management system use and recommended practices for homeowners, follow the primary recommendations section. Many of these recommendations may already be in practice; however, for the sake of thoroughness, they are reiterated here.

Prioritization

Based on the findings of this study, the order of prioritization for work, projects, and program enrollment within the Curtis Creek Watershed should be:

1. State Road 114 Subwatershed
2. Yeoman Ditch Subwatershed
3. Long Ditch Subwatershed
4. County Road 100 South Subwatershed
5. Headwaters Subwatershed
6. Mouth Subwatershed
7. Golf Course Subwatershed
8. Fair Oaks Subwatershed
9. Kosta Ditch Subwatershed
10. Elijah Ditch Subwatershed

The State Road 114 Subwatershed (4) is of top priority due to high pollutant loading rates especially total phosphorus, nitrogen, and *E. coli*. The mIBI indicated a "moderately" impaired system, and the drainage loaded disproportionate amounts of sediment and nutrient parameters relative to flow rate. Sixteen potential project sites where grassed waterways, filter strips, and wetland restoration could be implemented were located during aerial and windshield tours of this watershed.

Yeoman Ditch (2) is also of high priority. IDEM includes Yeoman Ditch on the 2002 303(d) list for nutrients, dissolved oxygen, total dissolved solids, and chlorides (IDEM, 2002). The Yeoman Ditch Subwatershed also contains three point source permitted discharges, one of which is routinely out of compliance. Yeoman Ditch disproportionately loaded more total phosphorus, soluble reactive phosphorus, total Kjeldahl nitrogen, nitrate, and total suspended solids relative to flow than any other stream based on samples collected during the study. Additionally, the phosphorus loading model estimated the annual phosphorus loading from the Yeoman Ditch Subwatershed was the second highest loading of any of the study subwatersheds (6441 kg/yr).

Long Ditch (5) is also listed as a priority subwatershed. During storm flows this ditch loaded more *E. coli* to Curtis Creek than any other study stream. Long Ditch is also included due to receiving the lowest mIBI score of any study reach (2.25) and because this stream does not contain any CRP acreage. Additionally, the phosphorus loading model estimated annual phosphorus loading per unit area to be the second highest (4.33 kg/ha-yr) of any of the subwatersheds.

The County Road 100 South (6) Subwatershed is also listed as a priority subwatershed. The representative reach in this subwatershed received the second lowest QHEI score (27) and possessed a "moderately" impaired biotic community. The CR 100 S Subwatershed also exhibited high nitrate-nitrogen and total Kjeldahl nitrogen loads during both storm and base flow and disproportionate loads of ammonia, total Kjeldahl nitrogen, and total phosphorus during both storm and base flow. Eleven potential restoration projects were identified during the aerial and windshield tours.

The Headwaters (9) Subwatershed is included as a priority subwatershed for several reasons. First, the subwatershed had a low mIBI score (2.5). Second, the phosphorus loading model estimated that annual phosphorus loading per unit area from the Headwaters Subwatershed was higher than loading from any other subwatershed (4.34 kg/ha-yr). A low percentage of CRP acreage within the subwatershed and the presence of six dairy barns containing 18,000 cattle also make the Headwaters Subwatershed a priority. Permits have been issued for the construction of two additional barns; implementation of conservation projects or innovative manure management projects, such as a dairy washwater treatment wetland, should be considered before construction begins. Seventeen potential conservation projects were noted in the Headwaters Subwatershed including filter strips, wetland restoration, and wind breaks.

The remaining five subwatersheds are of lower priority because they were generally responsible for lower amounts of pollutant loading and/or already contained more CRP land than the subwatersheds of top priority (Figure 75). Although the State Road 114 Subwatershed is of the highest priority implementing water quality improvement projects in any of the subwatersheds upstream of the State Road 114 Subwatershed will improve water quality within and downstream of the State Road 114 Subwatershed. Likewise, projects located in other subwatersheds should not be ignored simply due to lower subwatershed prioritization. Implementing any water quality improvement projects will increase water quality throughout the Curtis Creek Watershed. As will be discussed in the Funding Sources and Watershed Resources Section, the primary obstacle facing watershed projects is typically landowner willingness to participate (Osmond and Gale, 1995). Management and participation certainly should be encouraged in the remaining five subwatersheds of lower overall priority.

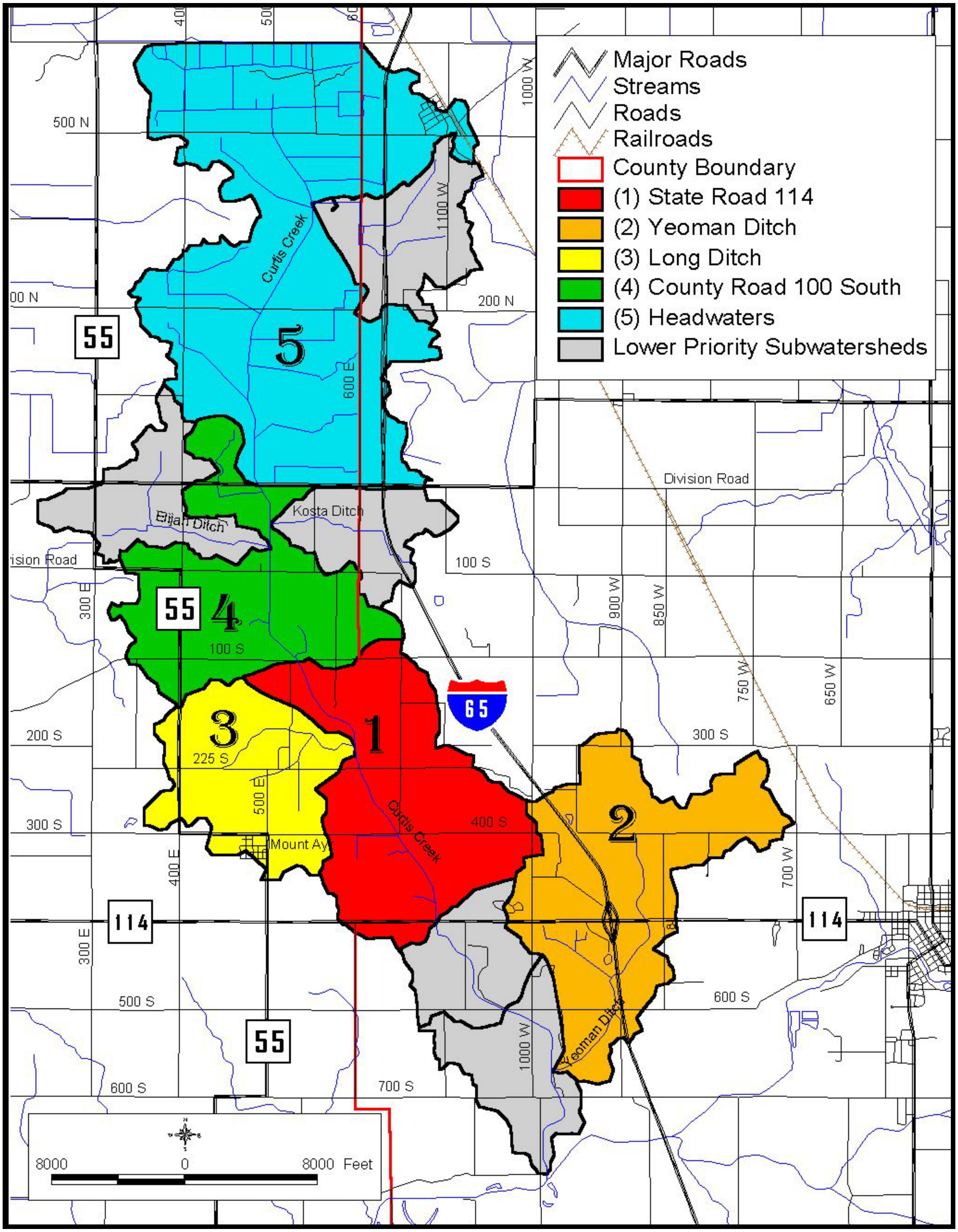


Figure 75. Subwatershed prioritization.

Primary Recommendations

1. Apply for Lake and River Enhancement (LARE) Watershed Land Treatment Funds to implement recommended BMPs and projects discussed for each subwatershed (Tables 44-52) based on subwatershed priority. Some of these projects include: wetland restoration, filter strip installation, allowing natural riparian vegetation growth, bank stabilization, livestock fencing, information and education efforts, buffer zone establishment, revegetation of exposed areas, wind break planting, and grassed waterway construction. This work should focus on interested landowners in identified critical areas first. Additional funding can be obtained from a variety of sources such as the Conservation Reserve Program, Wetland Reserve Program, and the Environmental Quality Incentives Program. These funds can be used separately or in conjunction with LARE Watershed Land Treatment funds. The Funding Sources Section details these and other funding programs.)

2. Assist permitted point source operations like the McDonald's Wastewater Treatment Plant or the Fair Oaks Dairy in implementing innovative waste management systems. Potential projects might include installing a wastewater treatment wetland at McDonald's. A wastewater treatment wetland can reduce the high nitrogen concentration present in McDonald's wastewater. Concurrently, treating the restaurant wastewater with a wetland treatment cell could increase effluent dissolved oxygen levels, thereby reducing the number of violations the McDonald's experiences each year. Constructing a an innovative treatment for washwater such as redesigning washwater storage ponds to maximize utility, employing horizontal subsurface flow systems, or introducing vegetation for wetland treatment could reduce nutrient leaching to groundwater in the blow sand region of the watershed where the Fair Oaks Dairy is in operation (O'Connor, 2002). Grant funding is available for projects of these types. (See the Funding Sources Section of this report for more specific information.)

3. Coordinate the projects referenced in recommendation #1 with the county drainage board to ensure that the project meets goals of both the Soil and Water Conservation District (SWCD) and the drainage board. For example, a SWCD tree-planting project in an area that is scheduled for drainage project de-brushing will not result in the optimum use of resources. In fact, a landowner may be more willing to participate in a cost-share program following ditch maintenance projects. Although none of the ditches are currently "on the books" for dredging, landowners within the Curtis Creek Watershed have petitioned the County Surveyor's office for assessment. Following assessment, much of Curtis Creek or its tributaries could be slated for maintenance projects. If any maintenance projects occur on Curtis Creek or its tributaries implementation of conservation practices along these ditches and in their immediate watersheds is strongly encouraged to prevent the need for such maintenance projects in the future. It is recommended that the SWCD work closely with the drainage boards to ensure that conservation practices advocated in the Indiana Drainage Handbook (Burke, 1996) are followed when planning and implementing projects. These conservation practices recommend tree preservation, vegetative stabilization and seeding, stream environment enhancement, and tree replacement even near regulated drains. Additionally, the Indiana Lakes Management Work Group, an Indiana Legislature authorized and governor

appointed group, also recommended that "drainage boards…implement all possible best management practices as indicated in the Indiana Drainage Handbook" (Case and Seng, 1999). The Group further suggested that the 1965 Indiana Drainage code (IC 36-9-27) be updated to "allow ditch maintenance assessments to be used to cost-share preventative measures such as streambank stabilization, riparian vegetation, and stable livestock access and stream crossings" and to "require drainage boards to develop a master plan (based on sound watershed management practices and with input from landowners) for each drain that proactively identifies sections of stream where landowners can restore protective riparian vegetation along stream sections that are never accessed for drain maintenance".

4. Extend management to the watershed level. Although streamside localized BMPs are important, research conducted in Wisconsin shows that the biotic community mostly responds to large-scale watershed influences rather than local riparian land use changes (Weigel et al., 2000). An example of working at the watershed-level is coordinating with producers to implement nutrient, pesticide, tillage, and coordinated resource management plans. It is important to note that the LARE Program will provide cost-share incentives for large-scale land practices like conservation tillage. Large-scale reductions in agricultural non-point source pollutions are necessary for stream health improvement (Osmond and Gale, 1995).

5. Provide information about streams within the Curtis Creek Watershed to local landowners. Landowners will be more likely to conserve and protect the creeks if they understand their value. The outreach program could include pointers on how landowners themselves can help protect the waterways.

General Recommendations

1. Develop a watershed or land use management plan. A watershed management plan documents current conditions within a watershed, sets water quality goals for the watershed based on stakeholders' desires, outlines a plan of how to reach the goals, and provides for monitoring of success toward reaching the goals. To be effective, all stakeholders must be included in the plan's development. Because it documents the current watershed conditions, this report can serve as a starting point for the development of a watershed management plan.

2. Before initiating watershed treatment projects, consider conducting a survey of landowners in the watershed to determine landowners' concern for water quality problems, to evaluate landowers' opinions of management systems, and to quantify the value of surface and groundwater quality improvement. Use this information to work with interested landowners to formulate individual Resource Management Plans.

3. Reach out to a school or other volunteer group to set up volunteer monitoring within the watershed through the Hoosier Riverwatch Program. This data will be a valuable resource by which to evaluate the success of projects implemented in the area.

4. Consider using innovative riparian management systems similar to the one discussed earlier in the Best Management Practice Section. Modified systems of this type would be especially beneficial for use in critical or vulnerable stream reaches where they could significantly impact non-point source pollution. Several critical stream reaches were identified by this study.

5. Invite producers and other landowners to visit successful project sites. There is no better advertisement than a success story. Focus on information dissemination and transfer by scheduling on-site field days during non-busy seasons.

6. Work with a bulk seed distributor to make native plant seed available in large quantities at low prices.

7. Work with the Newton and Jasper County Health Departments to ensure proper siting and engineering of septic systems. The use of alternative technology should be encouraged when conditions may compromise proper waste treatment. IDNR and USDA soil scientists in the area are a valuable resource for expertise in characterizing soils for septic use. Their knowledge could be tapped for future building and siting of systems. If building is necessary on a site where conditions are not suitable for a traditional system, alternative technology could be constructed and the site used as a demonstration and education/outreach tool.

8. Homeowners in the watershed should:
    a) Avoid lawn fertilizing near the stream's edge.
    b) Examine all drains that lead from roads, driveways, or rooftops to the stream, and consider alternate routes for these drains that would filter pollutants before they reach the water.
    c) Keep organic debris like lawn clippings, leaves, and animal waste out of the water.
    d) Avoid mowing up to the stream's edge; allow natural riparian vegetation growth.
    e) Properly maintain on-site wastewater treatment systems. Systems should be pumped regularly and leach fields should be properly cared for. Undue pressure on systems may be alleviated by water conservation practices as well.
    f) Maintain field drainage tiles and use filter strips around tile risers.
    g) Consider working with the Newton and Jasper County NRCS offices to formulate a Resource Management Plan for each individual property.

FUNDING SOURCES AND WATERSHED RESOURCES

Funding and other resources are important for the actual implementation of recommended management practices in a watershed. Several cost share and grant programs are available to help offset costs of watershed projects. Additionally, both human and material resources may be available in the watershed.

Funding Sources

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Lake associations and/or Soil and Water Conservation Districts (SWCDs) can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though the use of specific BMPs. As public awareness shifts towards watershed management, these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to lake and watershed associations for watershed management.

Lake and River Enhancement Program (LARE)

This is the program that funded this diagnostic study. LARE is administered by the Indiana Department of Natural Resources, Division of Soil Conservation. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the LARE program may fund lake and watershed specific construction actions up to $100,000 for a specific project or $300,000 for all projects on a specific lake or stream. Cost-share approved projects require a 0-25% cash or in-kind match, depending on the project. LARE also has a "watershed land treatment" component that can provide grants to SWCDs for multi-year projects. The funds are available on a cost-sharing basis with farmers who implement various BMPs. The watershed land treatment program is highly recommended as a project funding source for the Curtis Creek Watershed.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant

The 319 Grant Program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must meet specific criteria such as being listed in the state's 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement.

Section 104(b)(3) NPDES Related State Program Grants
Section 104(b)(3) of the Clean Water Act gives authority to a grant program called the National Pollutant Discharge Elimination System (NPDES) Related State Program Grants. These grants provide money for developing, implementing, and demonstrating new concepts or requirements that will improve the effectiveness of the NPDES permit program that regulates point source discharges of water pollution. Projects that qualify for Section 104(b)(3) grants involve water pollution sources and activities regulated by the NPDES program. The awarded amount can vary by project and there is a required 5% match.

Section 205(j) Water Quality Management Planning Grants
Funds allocated by Section 205(j) of the Clean Water Act are granted for water quality management planning and design. Grants are given to municipal governments, county governments, regional planning commissions, and other public organizations for researching point and non-point source pollution problems and developing plans to deal with the problems. According to the IDEM Office of Water Quality website: "The Section 205(j) program provides for projects that gather and map information on non-point and point source water pollution, develop recommendations for increasing the involvement of environmental and civic organizations in watershed planning and implementation activities, and implement watershed management plans. No match is required. For more information on the 319, 104(b)(3), and 205(j) grants, please see the IDEM website
http://www.in.gov/idem/water/planbr/wsm/Section205j_main.html.

Other Federal Grant Programs
The USDA and EPA award research and project initiation grants through the US National Research Initiative Competitive Grants Program and the Agriculture in Concert with the Environment Program.

Watershed Protection and Flood Prevention Program
The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture (USDA) and is administered by the Natural Resources Conservation Service (NRCS). Funding targets a variety of watershed activities including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects.

Conservation Reserve Program
As already discussed, the Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency (FSA). CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas that have a high potential for degrading water quality under traditional agricultural practices or areas that might make good wildlife habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Currently, the program offers continuous sign-up for practices like grassed waterways and filter strips. Participants in the program receive

cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is funded by the USDA and is administered by the NRCS. WRP is a subsection of the Conservation Reserve Program. This voluntary program provides funding for the restoration of wetlands on agricultural land. To qualify for the program, land must be restorable and suitable for wildlife benefits. This includes farmed wetlands, prior converted cropland, farmed wet pasture, farmland that has become a wetland as a result of flooding, riparian areas which link protected wetlands, and the land adjacent to protected wetlands that contribute to wetland functions and values. Landowners may place permanent or 30-year easements on land in the program. Landowners receive payment for these easement agreements. Restoration cost-share funds are also available. No match is required.

North American Wetland Conservation Act Grant Program

The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish, and other wildlife. The match for this program is on a 1:1 basis.

Wildlife Habitat Incentive Program

The Wildlife Incentive Program (WHIP) is funded by the USDA and administered by the NRCS. This program provides support to landowners to develop and improve wildlife habitat on private lands. Support includes technical assistance as well cost sharing payments. Those lands already enrolled in WRP are not eligible for WHIP. The match is 25%.

Forestry Incentives Program

The NRCS Forestry Incentives Program (FIP) provides cost-share dollars for forestry conservation activities like tree planting and timber stand improvement on privately-owned forest land. The program will share up to 65% of the cost of these and other related practices up to $10,000 per landowner per year. To be eligible for FIP, a particular parcel of land must be: smaller than 1,000 acres, be privately owned and non-industrial, be suitable for land management practices like aforestation, reforestation, or stand improvement, and be of sufficient productivity to yield marketable timber crops.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a voluntary program designed to provide assistance to producers to establish conservation practices in target areas where significant natural resource concerns exist. Eligible land includes cropland, rangeland, pasture, and forestland, and preference is given to applications which propose BMP installation that benefits wildlife. EQIP offers cost-share and technical assistance on tracts that are not eligible for continuous CRP enrollment. Certain BMPs receive up to 75% cost-share. In return, the producer agrees to withhold the land from production for five years. Practices that typically benefit wildlife include: grassed waterways, grass filter strips, conservation cover, tree planting, pasture and hay planting, and field borders. Best fertilizer and pesticide management practices are also eligible for EQIP cost-share.

Farmland Protection Program

The Farmland Protection Program (FPP) provides funds to help purchase development rights in order to keep productive farmland in use. The goals of FPP are: to protect valuable, prime farmland from unruly urbanization and development; to preserve farmland for future generations; to support a way of life for rural communities; and to protect farmland for long-term food security.

Debt for Nature

Debt for Nature is a voluntary program that allows certain FSA borrowers to enter into 10-year, 30-year, or 50-year contracts to cancel a portion of their FSA debts in exchange for devoting eligible acreage to conservation, recreation, or wildlife practices. Eligible acreage includes: wetlands, highly erodible lands, streams and their riparian areas, endangered species, or significant wildlife habitat, land in 100-year floodplains, areas of high water quality or scenic value, aquifer recharge zones, areas containing soil not suited for cultivation, and areas adjacent or within administered conservation areas.

Non-Profit Conservation Advocacy Group Grants

Various non-profit conservation advocacy groups provide funding for projects and land purchases that involve resource conservation. Ducks Unlimited and Pheasants Forever are two such organizations that dedicate millions of dollars per year to projects that promote and/or create wildlife habitat.

Watershed Resources

An important but often overlooked factor in accomplishing goals and completing projects in any watershed is resources within the watershed itself. These resources may be people giving of their time, local schools participating in projects, companies giving materials for project construction, or other donations. This study documents some of these available resources for the Curtis Creek Watershed. It is important to note that this list is not all-inclusive, and some groups and donors may have been missed.

Watershed Coordinator

IDEM and the USDA cosponsor three regional watershed conservationist positions. The watershed conservationist is an advocate for watershed level work in the region. Watershed conservationists can help direct actions of groups and stakeholders who are interested in working together to address problems in their watershed. They can help with everything from structuring public meetings to assisting with the compilation of a Watershed Management Plan. Their wealth of knowledge includes ideas about how to work with and respect all stakeholders in order to find the best plan for natural resource conservation within your watershed. Matt Jarvis is the regional watershed conservationist for the northern third of Indiana and has an office in Delphi, Indiana. His contact information is: Matt Jarvis, Regional Watershed Conservationist, Natural Resources Conservation Service, 1523 N. US Highway 421, Suite 2 Delphi, Indiana 46923-9396. He can also be contacted via phone at (765) 564-4480 or email at matt.jarvis@in.usda.gov.

Coordinated Resource Management

The Coordinated Resource Management (CRM) process is an organized approach to the identification of local concerns, evaluation of natural resources, development of alternative actions, assistance from technical specialists, implementation of a selected alternative, evaluation of implementation activities, and involvement of all interested parties who wish to participate in watershed action. The goal of the CRM process is the development of an effective Watershed Management Plan. Further CRM information and its complementary Watershed Action Guide can be downloaded from the USDA/NRCS website at http://www.in.nrcs.gov. The CRM gives guidance on how diverse groups of people can plan to maximize benefits to the greatest number of individuals while enhancing or maintaining the natural resource.

Hoosier Riverwatch

The Hoosier Riverwatch Program was started in 1994 by the State of Indiana to increase public awareness of water quality issues and concerns. Riverwatch is a volunteer stream monitoring program sponsored by the IDNR Division of Soil Conservation in cooperation with Purdue University Agronomy Department. Any citizen interested in water quality may volunteer to take a short training session held from May through October. Water monitoring equipment may be supplied to nonprofit organizations, schools, or government agencies by an equipment grant. Additionally, many SWCD offices (including the Jasper and Newton County SWCDs) have loaner equipment that can be borrowed. Several groups in the three counties actively participate in the Riverwatch Program. Table 77 contains information about groups that have conducted volunteer monitoring in the three counties. Because Curtis Creek has not been monitored through the Hoosier Riverwatch Program, more participation should be advocated within the study watershed especially since loaner equipment is readily available. More detailed information is available via the Hoosier Riverwatch web site at http://www.state.in.us/dnr/soilcons/riverwatch/.

TABLE 77. Groups that have participated in the Hoosier Riverwatch volunteer monitoring program in Jasper and Newton Counties.

County	Organization	City
Newton	Newton County SWCD	Brook
Jasper	Rensselaer Central Middle School	Rensselaer
Jasper	South Newton High School	Brook

Source: Lyn Hartman, Hoosier Riverwatch.

Indiana Department of Natural Resources

Bob Porch, the wildlife biologist at Willow Slough in Newton County, could offer assistance and management recommendations as conservation projects are built in the area especially if landowners have an interest in managing the property for wildlife. Bob has worked to provide several IDNR gamebird habitat areas in watersheds adjacent to the Curtis Creek Watershed. Mr. Porch can be contacted at: 5047 W 600 S, Morocco, Indiana 47963, (219) 285-2704.

Volunteer Groups

Volunteer groups can be instrumental in planning projects, implementing projects, and monitoring projects once they are installed. Although no streams in the study watershed have been monitored by Hoosier Riverwatch participants, both the Rensselaer Central Middle School and South Newton High School have participated in the program. The two schools are located in Rensselaer and Brook and are close to the study watershed. Involving the people living in the watershed, especially school-age children, is a good way to promote natural resource awareness and a good way to get data collected and projects completed. Oftentimes, data collected by volunteer groups may be the only available data for a watershed. This data is very valuable in helping to establish baseline trends with which to compare future samples.

Purdue Agricultural Center Research and Demonstration Projects

The Throckmorton-Purdue Agricultural Center (TPAC) in Lafayette participates in on-going agricultural research that is relevant to challenges producers face in northern Indiana. Researchers are currently conducting a wide variety of studies that have direct implications for better farming practices in the study watershed. A few of these projects include: 1) evaluating new insecticides to control crop pests like corn rootworm; 2) generating data for extension recommendations; 3) assessing new potassium soil testing techniques for improved ability to predict soil potassium supply; 4) evaluating cover crop effect on soil structure and nutrient conservation and availability under no-till and conventional tillage systems; 5) investigating the effects of filter strips on crop production via alterations in the community dynamics of arthropods, small mammals, and birds; 6) determining the effects that different crop rotations in tilled and no-till plots have on soil characteristics and erosion; 7) researching seed priming of prairie grasses to make planting more feasible for rapid establishment, erosion prevention, and general landscaping; 8) finding windbreak and filter strip planting designs with income potential; 9) developing an understanding of the interactions between crop pests and their natural predators. This research may provide insight on future management techniques that could be applicable to the Curtis Creek area. Additionally, the TPAC is home to a wetlands mitigation project that provides students, wildlife biologists, and preservation groups the opportunity for study and observation. An experimental septic system at the site also provides a training opportunity for septic installers and county sanitarians on how to lessen man's effect on rural watersheds.

<u>Obstacles for Watershed Projects</u>

Although the current study did not directly identify obstacles or special challenges for watershed-level projects in the Curtis Creek Watershed, data collected during a phone survey of hundreds of producers in the 21 Rural Clean Water Program (RCWP) project areas provides some information with respect to the most typical obstacle encountered in watershed projects: private landowner willingness to participate. The purpose of the survey was to evaluate difference between farmers who chose to participate in the RCWP projects and those who did not (Gale et al., 1993). Participation was positively correlated with the following factors: total acreage farmed, farm sales, property/equipment values, water pollution awareness, access to water quality/conservation materials and information, education level, willingness to take risks, availability of financial (cost-share) incentives, and level/frequency of one-to-one contact between project personnel and farmers (Osmond and Gale, 1995). (An example of a positive correlation would be that more producers participated if more cost-share incentives were available.) The study found that producers who were tenant farmers or were employed off-farm were less likely to participate in conservation programs. The main reason landowners did not participate was that they did not believe water quality to be a problem.

The Newton and Jasper County SWCD can take action to overcome this obstacle of private landowner willingness to participate in recommendation #4: providing landowners with information about water quality and the various programs (like LARE) that are available to cost-share best management initiatives. The SWCD may be able to use a LARE watershed land treatment project as a "showcase" project to build stakeholder interest and participation. The District could also encourage a local high school science class to initiate volunteer monitoring in the watershed in order to raise awareness and provide education for children.

LITERATURE CITED

Allan, J. David. 1995. Stream Ecology: structure and function of running waters. Chapman and Hall, London.

Alley, R.D. Inspection forms for Grandma's Home Cookin', McDonald's, and Trail Tree Wastewater Treatment Plants. 1998-2001.

APHA et al. 1998. Standard Methods for the Examination of Water and Wastewater, 20th edition. American Public Health Association, Washington, D.C.

Arora, K., S.K. Mickelson, J.L. Baker, D.P. Tierney, and C.J. Peters. 1993. Herbicide retention by vegetative buffer strips from runoff under natural rainfall. Trans. ASAE 39: 2155-2162.

Barbour et al. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish. 2nd Edition. USEPA, Office of Water. Washington, D.C. EPA 841-B99-002.

Barnes, J. and L. Osterholz. 1998. Soil Survey of Newton County, Indiana. USDA Soil Conservation Service and Purdue Agricultural Experiment Station.

Bowman, M.F. and R.C. Bailey. 1997. Does taxonomic resolution affect the multivariate description of the structure of freshwater benthic macroinvertebrate communities? Can. J. of Fisheries and Aquatic Sciences. 54:1802-1807.

Burke, Christopher. 1996. Indiana Drainage Handbook. Christopher Burke Engineering, Ltd., Indianapolis, IN.

Canada-Ontario Green Plan. 1997. No till: making it work. Ontario Federation of Agriculture. [web page] http://res2.agr.ca/london/gp/bmp/notillbmp.html.

Case, D. and P. Seng (Eds.). 1999. Final Report of the Indiana Lakes Management Work Group. Indiana Department of Environmental Management, Indianapolis, IN.

Clubine, S. 1995. Establishment and Importance of Native Warm Season Grasses. In: Summer Grazing in Missouri: Pasture Management and Beef Production. Missouri Department of Conservation, Clinton, Missouri, p. 39-43.

Cogger, C.G. 1989. Septic System Waste Treatment in Soils. Washington State University Cooperative Extension Department. EB1475.

Conservation Technology Information Center. No date. Benefits of High-Residue Farming. [web page] http://www.ctic.purdue.edu/Core4/CT/Checklist/Page3.html [Accessed February 9, 2001].

Conservation Technology Information Center. No date. Conservation Buffer Facts. [web page] http://www.ctic.purdue.edu/core4/buffer/bufferfact.html [Accessed March 3, 2000].

Correll, David L. 1998. The role of phosphorus in the eutrophication of receiving waters: a review. J. Environ. Qual., 27(2):261-266.

Crowther, R.A. and H.B.N. Hynes. 1977. The effect of de-icing salt on the drift of stream benthos. Environ. Poll. 14:113-126.

Daniels, R.B. and J.W. Gilliam. 1987. Sediment and chemical load reduction by grass and riparian buffers. Soil Sci. Soc. Am. J. 60: 246-251.

Dillaha, T.A., R.B. Reneau, S. Mostaghimi, and D. Lee. 1989. Vegetative filter strips for agricultural nonpoint source pollution control. Trans. ASAE 32: 513-519.

Eck, H.V. and B.A. Stewart. 1995. Manure. In: J.E. Rechcigl (ed.) Environmental Aspects of Soil Ammendments. Lewis Publishers, Boca Raton, Florida, p. 169-198.

Evans, M.G., K.J. Eck, B. Gauck, J.M. Krejci, J.E. Lake, and E.A. Matzat. 2000. Conservation Tillage Update: Keeping Soil Covered and Water Clean in the New Millennium. Purdue University Agronomy Department, West Lafayette, Indiana. AGRY-00-02.

Ferraro, S.P. and F.A. Cole. 1995. Taxonomic level sufficient for assessing pollution impacts in Southern California Bight macrobenthos- revisited. Env. Tox. and Chem. 14:1021-1040.

Furse et al. 1984. The influence of seasonal and taxonomic factors on the ordination and classification of running water sites in Great Britain and on the prediction of their macroinvertebrate communities. Freshwater Biology. 14:257-280.

Gallimore, L.E., N.T. Basta, D.E. Storm, M.E. Payton, R.H. Huhnke, and M.D. Smolen. 1999. Water treatment residual to reduce nutrients in surface runoff from agricultural land. Journal of Environmental Quality. 28:1474-1478.

Goetz, R. 2000. In Pursuit of Pesticides. Purdue Agricultures Magazine, Fall 2000 Issue [web page] http://www.agriculture.purdue.edu/agricultures/past/fall2000/features/feature_03.html. [Accessed October 2, 2001].

Grandma's Home Cookin' Wastewater Treatment Plant NPDES Permit. Permit Number IN0053422.

Grant, W. 1999. A Survey for Septic System Effects on Barbee Lake Chain, Indiana.

Gutschick, R.C. 1966. Bedrock Geology. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 1-20.

Halbeisen, J.L. 2001. Natural Nitrification Reduces Need for Commercial Fertilizers. In: U.S. EPA, Watershed Events. USEPA, Office of Water, Washington, DC. EPA 840-B01-002, p.8.

Hall D.W. and D.W. Risser. 1993. Effects of Agricultural Nutrient Management on Nitrogen Fate and Transport in Lancaster County, PA. AWRA Water Resources Bulletin. 29(1):55-76.

Hayes, J.C., B.J. Barfield, and R.I. Barnhisel. 1984. Performance of grass filters under laboratory and field conditions. Trans. ASAE 27: 1321-1331.

Heathwaite, L., A.N. Sharpley, and W. Gburek. 2000. A Conceptual Approach for Integrating Phosphorus and Nitrogen Management at Watershed Scales. J. Environ. Qual. 29:158-166.

Heidelberg College. Water Resources Program. 2002. [web page] http://www.heilelberg.edu/depts/wtr.html. [Accessed September 25, 2002].

Hilsenhoff, William L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. J. N. Am. Benthol. Soc. 7(1):65-68.

Homoya, M.A., B.D. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Indiana Academy of Science. Vol. 94. Indiana Natural Heritage Program. Indiana Department of Natural Resources, Indianapolis, Indiana.

Hynes, H.B.N. 1970. The Ecology of Running Waters, University of Toronto Press.

Indiana Administrative Code. 2000. Indiana Administrative Code, Article 2, Water Quality Standards.

Indiana Agricultural Statistics Service. 2002. Indiana Cattle Inventory Estimate. [web page] http://www.nass.usda.gov/in/cntest/cecat02.txt. [Accessed May 3, 2002].

Indiana Agrinews. 2001. Tillage practices good for farm practices, environment. Indianapolis, Indiana, July 13, 2001. [web page] http://www.agrinews-pubs.com.

Indiana Department of Environmental Management. No date. Scoring criteria for the family level macroinvertebrate Index of Biotic Integrity (mIBI). Biological Studies Section, Indianapolis, Indiana.

Indiana Department of Environmental Management. No. date. Confined Feeding Operation Files. File Log #651, 3535, 6015, 6036, 6364, 6065, 6110, 6153. Indianapolis, Indiana.

Indiana Department of Environmental Management. 1995. Indiana Water Quality Report. Department of Environmental Management, Indianapolis, Indiana.

Indiana Department of Environmental Management. 2000. Indiana Water Quality Report. Department of Environmental Management, Indianapolis, Indiana.

Indiana Department of Environmental Management. 303(d) List. Office of Water Quality, Watershed Management Section, Indianapolis, Indiana.

Indiana Department of Environmental Management. 2002. Indiana Confined Feeding Regulation Program Guidance Manual. Office of Land Quality, Solid Waste Section, Indianapolis, Indiana.

Indiana University/Purdue University, Ft. Wayne. 1996. Characteristics of Fine Grained Soils and Glacial Deposits in Northeastern Indiana for On-Site Wastewater Disposal Systems. Department of Continuing Education, Ft. Wayne, Indiana.

Isenhart, T.M., R.C. Schultz, and J.P. Colletti. 1997. Watershed Restoration and Agricultural practices in the Midwest: Bear Creek of Iowa. In: Williams, J.E., C.A. Wood, and M.P. Dombeck (eds.) Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, Maryland, p. 318-334.

J.F. New and Associates, Inc. J. F. New Native Plant Nursery 2001 Wholesale Catalog. Walkerton, Indiana.

Joint Committee on Atomic Energy. 1954. Hearing before the Subcommittee on Research and Development. United States Printing Office, Washington, DC.

Jones, D.D. and J.E. Yahner. 1994. Operating and Maintaining the Home Septic System. Purdue University Cooperative Extension Service. ID-142.

Jones, W. 1996. Indiana Lake Water Quality Update for 1989-1993. Indiana Department of Environmental Management. Clean Lakes Program. Indianapolis, Indiana.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspectives on water quality goals. Environ. Mgmt. 5:55-68.

Kenimer, A.L., M.J. McFarland, F.L. Mitchell, and J.L. Lasswell. 1997. Wetlands for agricultural non-point source pollution control. Texas A&M University, Department of Agricultural Engineering. [web page] http://twri.tamu.edu/research/other/kenimer_1.html. [Accessed September 19, 2001].

Kladivko, E. 1999. Literature Review of Tile Drainage Studies. Report to the American Crop Protection Association.

Klingeman, P.C. and J.B. Bradley. 1976. Willamette River Basin streambank stabilization by natural means. U.S. Army Corps of Engineers, Portland, Oregon.

Leeds, R., L.C. Brown, M.R. Sulc, and L. VanLieshout. 1993. Vegetative Filter Strips: Application, Installation and Maintenance. Extension Fact Sheet, The Ohio State University Extension, AEX-467.

Leeds, R., D.L. Forster, and L.C. Brown. 1997. Vegetative Filter Strips: Economics. Ohio State University Extension. [web page] http://hermes.ecn.purdue.edu:8001/cgi/convertwq?8186. [Accessed September 19, 2001].

Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana.

Marchant, R.L. et al. 1995. Influence of sample quantification and taxonomic resolution on the ordination of macroinvertebrate communities from running waters in Victoria, Australia. Marine and Freshwater Research. 46:501-506.

McDonald's Restaurant Wastewater Treatment Plant NPDES Permit. NPDES Permit Number 0063933.

Mickelson, S.K. and J.L. Baker. 1993. Buffer strips for controlling herbicide runoff losses. Paper no. 932084. Am. Soc. Agric. Eng., St. Joseph, Michigan.

National Academy of Sciences, National Academy of Engineering, Environmental Studies Board. 1972. Water quality criteria, a report of the Committee on Water Quality Criteria.

National Climatic Data Center. 1976. Climatography of the United States. No.60.

National Conservation Buffer Council. 1999. Environmental Benefits of Buffers. [web page] http://www.buffercouncil.org/benefits.html [Accessed February 9, 2001].

National Research Council. 1993. Soil and Water Quality: Agenda for Agriculture. National Academy Press, Washington, D.C.

Natural Resources Conservation Service. 2001. [web page.] Indiana Field Office Technical Guide – Section III Conservation Management Systems. [web page] http://www.in.nrcs.usda.gov/PlanningandTechnology/fotg/section3/section.3html. [Accessed August 16, 2001].

Natural Resources Conservation Service. 2000. Conservation Practice Standard for Filter Strips. Code 393.

O'Connor, K.A. 2002. OCWD's Dairy Washwater Treatment Wetlands Demonstration Project. Land and Water. 46(2):40-45.

O'Leary, M, N. Thomas, D. Eppich, D. Johannesen, S. Apfelbaum. 2001. Watershed diagnostic study of the Little Calumet-Galien River Watershed. Indiana Department of Natural Resources, Indianapolis, Indiana.

Ohio Administrative Code. 3745-1, Ohio Water Quality Standards. Ohio Environmental Protection Agency.

Ohio EPA. 1989. Qualitative habitat evaluation index manual. Division of Water Quality Planning and Assessment, Columbus, Ohio.

Ohio EPA. 1995. Biological and water quality study of Little Miami River and selected tributaries, Clarke, Greene, Montgomery, Warren, Clermont, and Hamilton Counties, Ohio. Volume 1. OEPA Tech. Rept. No. MAS/1994-12-11. Ohio EPA, Division of Surface Water, Monitoring and Assessment Section, Columbus, Ohio.

Ohio EPA. 1999. Association between nutrients, habitat, and the aquatic biota in Ohio rivers and streams. Ohio EPA Technical Bulletin MAS/1999-1-1, Columbus.

Olem, H. and G. Flock, eds. 1990. Lake and reservoir restoration guidance manual. 2nd edition. EPA 440/4-90-006. Prepared by North American Lake Management Society for U.S. Environmental Protection Agency, Washington, DC.

Osmond, D.L. and J.A. Gale. 1995. Farmer participation in solving the non-point source pollution problem. North Carolina Extension Service. [web page] http://h2osparc.wq.ncsu.edu/brochures/eight.html. [Accessed October 2, 2001].

Osmond, D.L., J. Spooner, and D.E. Line. 1995. Systems of BMPs for Controlling Agricultural Non-Point Source Pollution. North Carolina Cooperative Extension Service. [web page] http://h2osparc.wq.ncsu.edu/brochures/six.html. [Accessed October 2, 2001].

Petty, R.O. and M.T. Jackson. Plant communities. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 264-296.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. US Environmental Protection Agency, Washington, DC, EPA/440/4-89/001.

Purdue Applied Meteorology Group. 2002. Indiana Climate Page [web page] http://shadow.agry.purdue.edu/sc.index.html [Accessed December 30, 2002]

Purdue Cooperative Extension Service. 1998. Diary Manure Management Planning (MMP). ID-208. Purdue University Cooperative Extension Service and Natural Resources Conservation Service, West Lafayette, Indiana.

Purdue Cooperative Extension Service. 2002. Indiana T by 2000 Watershed Soil Loss Transects Data Set. Crawfordsville, Indiana.

Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Division of Water Quality Planning and Assessment, Columbus.

Rankin, E.T. 1995. Habitat indices in water resource quality assessment, in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. CRC Press/Lewis Publishers, Ann Arbor.

Rechhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients. EPA 440/5-80-11. U.S. Environmental Protection Agency, Washington, DC.

Reed, S.C. and D.S. Brown. 1992. Constructed wetland design: the first generation. Water Environ. Res. 64(6):776-781.

Robertson, B. 1990. Iroquois River, Fish Management Report. Indiana Department of Natural Resources. Indianapolis, Indiana.

Rouch, J. 2000. Water Quality Monitoring Joint Project. St. Joseph River Basin Commission and St. Joseph, Elkhart, LaGrange, Noble, Steuben, and Kosciusko County Soil and Water Conservation Districts.

Schmitt, T.J., M.G. Dosskay, and K.D. Hoagland. 1999. Filter strip performance and processes for different vegetation, widths, and contaminants. Journal of Environmental Quality, 28(5): 1479-1489.

Schneider, A.F. 1966. Physiography. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 40-56.

Schultz, R.C., J.P. Colletti, T.M. Isenhart, W.W. Simpkins, C.W. Mise, and M.L. Thompson. 1995. Agroforestry Systems. 29(3):201-226.

Sechrist, P. Inspection forms from Grandma's Home Cookin', McDonald's, and Trail Tree Wastewater Treatment Plants. 1996-1997.

Sharp Bros. Seed Company. 2001. [web page] Sharp Bros. Seed Company. [Accessed November 2001]. http://www.sharpseed.com/

Sharpley, A.N. and S.J. Smith. 1994. Wheat tillage and water quality in the southern plains. Soil Tillage Res. 30:33-38.

Silcox, C.A., B.A. Robinson, and T.C. Willoughby. 2001. Concentrations of Escherichia coli in Streams in the Kankakee and Lower Wabash River Watersheds in Indiana, June-September 1999. U.S. Geological Survey in cooperation with the Indiana Department of Environmental Management. USGS Water Resources Investigations Report 01-4018.

Simon, T.P. 1991. Development of Index of Biotic Integrity expectations for the ecoregions of Indiana. I. Central Corn Belt Plain. U.S. Environmental Protection Agency, Region V, Environmental Sciences Division, Monitoring and Quality Assurance Branch: Ambient Monitoring Section, Chicago, Illinois. EPA 905/9-91/025.

Smallwood, B. and L. Osterholz. 1990. Soil Survey of Jasper County, Indiana. USDA Soil Conservation Service and Purdue Agricultural Experiment Station.

Smith, G.M. E.M. Gilbert, G.S. Byran, R.I. Evans, and J.F. Stauffer. 1953. A Textbook of General Botany. The MacMillan Company, New York.

STATS Indiana. 2002. Indiana Population Estimates, Projections, and Historic Census Counts. [web page] http://www.stats.indiana.edu/c2k/c2kframe.html. [Accessed March 7, 2002].

Sutton, A. L. 1994. Proper animal manure utilization. Nutrient Management a supplement to the Journal of Soil and Water Conservation. 49 (2): 65-70.

Thomas, J.A. 1996. Soil Characteristics of "Buttermilk Ridge" Wabash Moraine, Wells County Indiana. Notes for the IU/PU (Ft. Wayne) Soils Course: Characteristics of Fine-Grained Soils and Glacial Deposits in Northeastern Indiana for On-Site Wastewater Disposal Systems.

Trail Tree Truck Plaza Wastewater Treatment Plant NPDES Permit. NPDES Permit Number 0041904.

Turtola, E. and A. Paajanen. 1995. Influence of improved subsurface drainage on phosphorus losses and nitrogen leaching from a heavy clay soil. Agric. Water Manage. 28:295-310.

Ulrich, H.P. 1966. Soils. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 57-90.

Unger, P.W., A.N. Sharpley, J.L. Steiner, R.I. Papendick, and W.M. Edwards. 1998. Soil management research for water conservation quality. In: F.J. Pierce and W.W. Frye (eds.) Advances in Soil and Water Conservation. Sleeping Bear Press, Ann Arbor, Michigan, p. 69-97.

United States Census of Agriculture, United States Department of Commerce. 1997. Indiana Farm Land Use History, Newton and Jasper Counties, Indiana. [web page] http://www.nass.usda.gov/in/historic [Accessed March 7, 2002].

United States Census of Agriculture, United States Department of Commerce. 2002. [web page] Indiana Cattle Inventory. http://www.nass/usda/gov/in/cntest/cecat02.txt. [Accessed April 24, 2002]

United States Department of Agriculture. 1997. The Conservation Reserve Program. Washington, D.C. PA-1603.

United States Environmental Protection Agency. 1976. Quality Criteria for Water. U.S. Environmental Protection Agency, Washington, D.C.

United States Environmental Protection Agency. 1989. Health Advisory Summaries. Office of Water.

United States Environmental Protection Agency. 1998. 1998 Update of Ambient Water Quality Criteria for Ammonia. EPA-822-F-98-005. U.S. Environmental Protection Agency, Washington, D.C.

United States Environmental Protection Agency. 2002. Ground Water and Drinking Water. Current Drinking Water Standards. [web page] http://www.epa.gov/safewater/mcl.html. [Accessed September 25, 2002].

United States Environmental Protection Agency. 2002. Envirofacts Data Warehouse. [web page] http://www.epa.gov/enviro. [Accessed March 13, 2002].

United States Geological Survey. 2002. [web page] USGS 05522500 Iroquois River at Rensselaer, Indiana. http://waterdata.usgs.gov/in/nwis/uv?05522500. [Accessed May 15, 2002; June 22, 2002; August 6, 2002]

United States Geological Survey. 2002 [web page] Water quality information: Data. http://water.usgs.gov/owq/data.html. [Accessed May 20, 2002]

Waite, I.R. et al. 2000. Comparing strengths of geographic and nongeographic classifications of stream benthic macroinvertebrates in the Mid-Atlantic Highlands, USA. J. N. Am. Benthol. Soc. 19(3):429-441.

Walker, R.D. 1978. Task force on Agricultural Nonpoint Sources of Pollution Subcommittee on soil Erosion and Sedimentation. Illinois Institute for Environmental Quality, 72pp.

Wang, E., W.L. Harman, J.R. Williams, and J.M. Sweeten. 2002. Profitability and nutrient losses of alternative manure application strategies with conservation tillage. Journal of Soil Conservation. 57(4):221-228.

Water Quality Laboratory. 1996. Interpretation Letter. Heidelberg College, Tiffin, Ohio.

Waters, T.F. 1995. Sediment in Streams: Sources, Biological Effects, and Control. American Fisheries Society Monograph 7. Bethesda, Maryland, 251pp.

Wayne, W.J. 1966. Ice and land: a review of the tertiary and Pleistocene history of Indiana. In: Lindsey, A.A. (ed.) Natural Features of Indiana. Indiana Academy of Science, Indiana State Library, Indianapolis, Indiana, p. 21-39.

Weigel, B.M. J. Lyons, L.K. Paine, S.I. Dodson, and D.J. Undersander. 2000. Using stream macroinvertebrates to compare riparian land use practices on cattle farms in southwestern Wisconsin. Journal of Freshwater Ecology. 15(1):93-106.

West, T.D., G.C. Steinhardt, and T.J. Vyn. 1999. Tillage Research Annual Report 1999. Purdue University Agronomy Department, West Lafayette, Indiana.

Wetzel, R.G. 1993. Constructed wetlands; scientific foundations are critical. In: G.S. Moshiri (ed.) Constructed Wetlands for Water Quality Improvement. Lewis Publishers, Boca Raton, Florida.

White, G. Unpublished. 9 Chemical Tests: Typical Ranges. In: Safety and Chemical Testing Instructions. Hoosier Riverwatch, Revised June 22, 1999.

Yadav, S.N. 1997. Formulation and estimation of nitrate-nitrogen leaching from corn cultivation. J. Environ. Qual. 26:808-814.

APPENDICES

APPENDIX 1:

Detailed Land Use and Land Cover for the Study Subwatersheds

APPENDIX 1. Detailed Land Use and Land Cover for the Study Subwatersheds.

TABLE 1.1. Mouth of Curtis Creek Subwatershed.

Landcover	Area (acres)	Area (ha)	%
Agriculture Row Crops	988.00	400.00	77.61
Agriculture Pasture/Hay	129.00	52.23	10.13
Agriculture Small Grains	0.0	0.0	0.0
Deciduous Forest	73.00	29.55	5.73
Evergreen Forest	20.00	8.10	1.57
Mixed Forest	0.0	0.0	0.0
Grassland/Herbaceous	16.00	6.48	1.26
Emergent Herbaceous Wetlands	5.00	2.02	0.39
Woody Wetland	33.00	13.36	2.59
High Intensity Commercial	0.0	0.0	0.0
High Intensity Residential	0.0	0.0	0.0
Low Intensity Residential	0.03	0.01	0.00
Open Water	2.00	0.81	0.16
Recreation/Park Land	7.00	2.83	0.55
Bare Rock/Sand/Clay	0.0	0.0	0.0
TOTAL	**1273.03**	**515.40**	**100%**

TABLE 1.2. Yeoman Ditch Subwatershed.

Landcover	Area (acres)	Area (ha)	%
Agriculture Row Crops	2973.00	1203.64	77.86
Agriculture Pasture/Hay	377.00	152.63	9.87
Agriculture Small Grains	1.00	0.40	0.03
Deciduous Forest	268.00	108.50	7.02
Evergreen Forest	26.00	10.53	0.68
Mixed Forest	0.0	0.0	0.0
Grassland/Herbaceous	34.00	13.77	0.89
Emergent Herbaceous Wetlands	12.00	4.86	0.31
Woody Wetland	60.00	24.29	1.57
High Intensity Commercial	34.00	13.77	0.89
High Intensity Residential	4.00	1.62	0.10
Low Intensity Residential	13.00	5.26	0.34
Open Water	14.00	5.67	0.37
Recreation/Park Land	2.00	0.81	0.05
Bare Rock/Sand/Clay	0.20	0.08	0.01
TOTAL	**3818.20**	**1545.83**	**100%**

TABLE 1.3. Golf Course Subwatershed.

Landcover	Area (acres)	Area (ha)	%
Agriculture Row Crops	425.00	172.06	41.01
Agriculture Pasture/Hay	96.00	38.87	9.26
Agriculture Small Grains	0.0	0.0	0.0
Deciduous Forest	319.00	129.15	30.78
Evergreen Forest	31.00	12.55	2.99
Mixed Forest	0.0	0.0	0.0
Grassland/Herbaceous	16.00	6.48	1.54
Emergent Herbaceous Wetlands	6.00	2.43	0.58
Woody Wetland	35.00	14.17	3.38
High Intensity Commercial	0.20	0.08	0.02
High Intensity Residential	0.02	0.01	0.00
Low Intensity Residential	1.00	0.40	0.10
Open Water	1.00	0.40	0.10
Recreation/Park Land	106.00	42.91	10.23
Bare Rock/Sand/Clay	0.0	0.0	0.0
TOTAL	**1036.22**	**419.52**	**100%**

TABLE 1.4. State Road 114 Subwatershed.

Landcover	Area (acres)	Area (ha)	%
Agriculture Row Crops	2477.00	1002.83	67.45
Agriculture Pasture/Hay	576.00	233.20	15.69
Agriculture Small Grains	0.0	0.0	0.0
Deciduous Forest	370.00	149.80	10.08
Evergreen Forest	28.00	11.34	0.76
Mixed Forest	0.80	0.32	0.02
Grassland/Herbaceous	98.00	39.68	2.67
Emergent Herbaceous Wetlands	4.00	1.62	0.11
Woody Wetland	117.00	47.37	3.19
High Intensity Commercial	0.0	0.0	0.0
High Intensity Residential	0.0	0.0	0.0
Low Intensity Residential	0.60	0.24	0.02
Open Water	0.0	0.0	0.0
Recreation/Park Land	0.70	0.28	0.02
Bare Rock/Sand/Clay	0.0	0.0	0.0
TOTAL	**3672.10**	**1486.68**	**100%**

TABLE 1.5. Long Ditch Subwatershed.

Landcover	Area (acres)	Area (ha)	%
Agriculture Row Crops	1807.00	731.58	81.60
Agriculture Pasture/Hay	222.00	89.88	10.03
Agriculture Small Grains	0.0	0.0	0.0
Deciduous Forest	90.00	36.44	4.06
Evergreen Forest	9.00	3.64	0.41
Mixed Forest	0.0	0.0	0.0
Grassland/Herbaceous	30.00	12.15	1.35
Emergent Herbaceous Wetlands	0.40	0.16	0.02
Woody Wetland	23.00	9.31	1.04
High Intensity Commercial	4.00	1.62	0.18
High Intensity Residential	0.80	0.32	0.04
Low Intensity Residential	24.00	9.72	1.08
Open Water	0.20	0.08	0.01
Recreation/Park Land	4.00	1.62	0.18
Bare Rock/Sand/Clay	0.0	0.0	0.0
TOTAL	**2214.40**	**896.52**	**100%**

TABLE 1.6. County Road 100 South Subwatershed.

Landcover	Area (acres)	Area (ha)	%
Agriculture Row Crops	2209.00	894.33	72.16
Agriculture Pasture/Hay	293.00	118.62	9.57
Agriculture Small Grains	0.20	0.08	0.01
Deciduous Forest	437.00	176.92	14.28
Evergreen Forest	21.00	8.50	0.69
Mixed Forest	0.0	0.0	0.0
Grassland/Herbaceous	61.00	24.70	1.99
Emergent Herbaceous Wetlands	10.00	4.05	0.33
Woody Wetland	30.00	12.15	0.98
High Intensity Commercial	0.0	0.0	0.0
High Intensity Residential	0.0	0.0	0.0
Low Intensity Residential	0.0	0.0	0.0
Open Water	0.0	0.0	0.0
Recreation/Park Land	0.0	0.0	0.0
Bare Rock/Sand/Clay	0.0	0.0	0.0
TOTAL	**3061.20**	**1239.35**	**100%**

TABLE 1.7. Elijah Ditch Subwatershed.

Landcover	Area (acres)	Area (ha)	%
Agriculture Row Crops	731.00	295.95	56.45
Agriculture Pasture/Hay	90.00	36.44	6.95
Agriculture Small Grains	0.0	0.0	0.0
Deciduous Forest	415.00	168.02	32.05
Evergreen Forest	12.00	4.86	0.93
Mixed Forest	0.0	0.0	0.0
Grassland/Herbaceous	33.00	13.36	2.55
Emergent Herbaceous Wetlands	8.00	3.24	0.62
Woody Wetland	6.00	2.43	0.46
High Intensity Commercial	0.0	0.0	0.0
High Intensity Residential	0.0	0.0	0.0
Low Intensity Residential	0.0	0.0	0.0
Open Water	0.0	0.0	0.0
Recreation/Park Land	0.0	0.0	0.0
Bare Rock/Sand/Clay	0.0	0.0	0.0
TOTAL	**1295.00**	**524.29**	**100%**

TABLE 1.8. Kosta Ditch Subwatershed.

Landcover	Area (acres)	Area (ha)	%
Agriculture Row Crops	489.00	197.98	47.51
Agriculture Pasture/Hay	73.00	29.55	7.09
Agriculture Small Grains	0.0	0.0	0.0
Deciduous Forest	408.00	165.18	39.64
Evergreen Forest	11.00	4.45	1.07
Mixed Forest	0.0	0.0	0.0
Grassland/Herbaceous	10.00	4.05	0.97
Emergent Herbaceous Wetlands	3.00	1.21	0.29
Woody Wetland	15.00	6.07	1.46
High Intensity Commercial	20.00	8.10	1.94
High Intensity Residential	0.0	0.0	0.0
Low Intensity Residential	0.10	0.04	0.01
Open Water	0.10	0.04	0.01
Recreational Park Land	0.0	0.0	0.0
Bare Rock/Sand/Clay	0.0	0.0	0.0
TOTAL	**1029.20**	**416.68**	**100%**

TABLE X.9. Headwaters of Curtis Creek Subwatershed.

Landcover	Area (acres)	Area (ha)	%
Agriculture Row Crops	6555.00	2653.85	82.70
Agriculture Pasture/Hay	652.00	263.97	8.23
Agriculture Small Grains	4.00	1.62	0.05
Deciduous Forest	456.00	184.62	5.75
Evergreen Forest	64.00	25.91	0.81
Mixed Forest	0.0	0.0	0.0
Grassland/Herbaceous	105.00	42.51	1.32
Emergent Herbaceous Wetlands	2.00	0.81	0.03
Woody Wetland	30.00	12.15	0.38
High Intensity Commercial	31.00	12.55	0.39
High Intensity Residential	3.00	1.21	0.04
Low Intensity Residential	21.00	8.50	0.26
Open Water	3.00	1.21	0.04
Recreational Park Land	0.0	0.0	0.0
Bare Rock/Sand/Clay	0.20	0.08	0.00
TOTAL	**7926.20**	**3208.99**	**100%**

TABLE X.10. Fair Oaks Subwatershed.

Landcover	Area (acres)	Area (ha)	%
Agriculture Row Crops	694.00	280.97	55.92
Agriculture Pasture/Hay	461.00	186.64	37.15
Agriculture Small Grains	1.00	0.40	0.08
Deciduous Forest	47.00	19.03	3.79
Evergreen Forest	5.00	2.02	0.40
Mixed Forest	0.0	0.0	0.0
Grassland/Herbaceous	16.00	6.48	1.29
Emergent Herbaceous Wetlands	1.00	0.40	0.08
Woody Wetland	2.00	0.81	0.16
High Intensity Commercial	13.00	5.26	1.05
High Intensity Residential	0.0	0.0	0.0
Low Intensity Residential	0.0	0.0	0.0
Open Water	1.00	0.40	0.08
Recreational Park Land	0.0	0.0	0.0
Bare Rock/Sand/Clay	0.0	0.0	0.0
TOTAL	**1241.00**	**502.43**	**100%**

APPENDIX 2:

Structural and Managerial Conservation Practices

APPENDIX 2. Structural and managerial conservation practices that are relevant for use in the Curtis Creek Watershed. These conservation practices were adapted from the National Handbook of Conservation Practices. Their listing here does not imply endorsement by J.F. New & Associates, nor will every practice be relevant to every situation.

TABLE 2.1 Structural conservation practices that are relevant for use in the Curtis Creek Watershed.

Alley Cropping	Field Border	Sediment Basin
Access Road	Filter Strip	Stream Habitat Improvement and Management
Anionic Polyacrylamide (PAM) Erosion Control	Fish Passage	Streambank and Shoreline Protection
Animal Trails and Walkways	Floodwater Diversion	Structure for Water Control
Channel Vegetation	Floodway	Subsurface Drain
Clearing and Snagging	Grade Stabilization Structure	Surface Drainage, Field Ditch
Composting Facility	Grassed Waterway	Tree-Shrub Establishment
Conservation Cover	Grazing Land Mechanical Treatment	Tree/Shrub Pruning
Constructed Wetland	Heavy Use Area Protection	Underground Outlet
Contour Buffer Strips	Hedgerow Planting	Vegetative Buffers
Contour Farming	Herbaceous Wind Barriers	Waste Storage Facility
Controlled Drainage	Land Clearing	Waste Treatment Lagoon
Cover Crop	Lined Waterway or Outlet	Water and Sediment Control Basin
Critical Area Planting	Obstruction Removal	Water Table Control
Dam, Diversion	Open Channel	Wetland Creation
Dam, Floodwater Retarding	Pond	Wetland Enhancement
Dam, Mulitple Purpose	Range Planting	Wetland Restoration
Dike	Riparian Forest Buffer	Wildlife Watering Facility
Diversion	Riparian Herbaceous Cover	Windbreak/Shelterbelt Establishment
Fence	Rock Barrier	Windbreak/Shelterbelt Renovation

Source: National Handbook of Conservation Practices: **http://www.ncg.nrcs.usda.gov/nhcp_2.html**. Practice standards are available online at the above website or by contacting your county NRCS office.

TABLE 2.2 Managerial conservation practices that are relevant for use in the Curtis Creek Watershed.

Bedding	Nutrient Management	Roof Runoff Management
Brush Management	Pasture and Hay Planting	Row Arrangement
Conservation Crop Rotation	Pest Management	Runoff Management System
Deep Tillage	Prescribed Burning	Shallow Water Management for Wildlife
Early Successional Habitat Development/Management	Prescribed Grazing	Stream Habitat Improvement and Management
Fishpond Management	Residue Management, Mulch Till	Stripcropping
Forage Harvest Management	Residue Management, No-Till and Strip Till	Upland Wildlife Habitat
Irrigation Water Management	Residue Management, Ridge Till	Waste Utilization
Manure Transfer	Residue Management, Seasonal	Water Table Control
Mulching	Restoration and Management of Declining Habitats	Wetland Wildlife Habitat Management

Source: National Handbook of Conservation Practices: **http://www.ncg.nrcs.usda.gov/nhcp_2.html**. Practice standards are available online at the above website or by contacting your county NRCS office.

APPENDIX 3:

Photos from the Riparian Management System Model in the Bear Creek Watershed, Iowa (Isenhart et al., 1997)

Bear Creek riparian management site from the Isenhart et al., 1997 study. Top photo shows site in March 1990, prior to buffer strip establishment. The bottom photo shows the same site in June 1994 after five growing seasons. Used with permission from the American Fisheries Society.

Wetland component of the Bear Creek riparian management system model from the Isenhart et al., 1997 study. Photo was taken in August 1994, a few months after construction. The water control structure can be seen in the foreground. Used with permission from the American Fisheries Society.

APPENDIX 4:

Endangered, Threatened, and Rare Species List,
Curtis Creek Watershed

March 19, 2002

ENDANGERED, THREATENED AND RARE SPECIES,
HIGH QUALITY NATURAL COMMUNITIES, AND SIGNIFICANT NATURAL AREAS DOCUMENTED
FROM THE CURTIS CREEK WATERSHED, JASPER & NEWTON COUNTIES, INDIANA

TYPE	SPECIES NAME	COMMON NAME	STATE	FED	LOCATION	DATE	COMMENT
FAIR OAKS							
Bird	BARTRAMIA LONGICAUDA	UPLAND SANDPIPER	SE	**	T30NR07W 30	1997	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR07W 06 NWQ NWQ NEQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR07W 18 SWQ NWQ SWQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR07W 18 SEQ SEQ SEQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR07W 19 SWQ NWQ NWQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR07W 06 NWQ NWQ SWQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR07W 08 NWQ NEQ NWQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR07W 18 SWQ NEQ SWQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR07W 07 SWQ SEQ NWQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR08W 11 NEQ NEQ NWQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR08W 03 SWQ SEQ SWQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T31NR08W 34 SWQ SEQ SEQ	1988	
Mammal	GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	T30NR08W 15 SEQ SWQ SWQ	1988	
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	T30NR08W NEAR FAIR OAKS	1984	
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	T30NR08W 14	1987	
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	T30NR07W 19 SWQ NWQ NWQ	1988	
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	T30NR08W 11 NWQ NWQ	1988	
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	T30NR07W 18 NWQ SWQ	1988	
Reptile	EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	T30NR08W 24 SEQ	1946	
Reptile	THAMNOPHIS PROXIMUS	WESTERN RIBBON SNAKE	SSC	**	T30NR08W 35	NO D	
Savanna	SAVANNA - SAND DRY	DRY SAND SAVANNA	SG	**	T30NR08W 27	1988	
Savanna	SAVANNA - SAND DRY	DRY SAND SAVANNA	SG	**	T30NR08W 03	1988	
Vascular Plant	ASTER SERICEUS	WESTERN SILVERY ASTER	SR	**	T30NR07W 06 NWQ NEQ	1981	
Vascular Plant	POLYGONUM HYDROPIPEROIDES	NORTHEASTERN SMARTWEED	ST	**	T30NR09W 32 NWQ NWQ	1984	
Vascular Plant	TALINUM RUGOSPERMUM	PRAIRIE FAME-FLOWER	ST	**	T30NR08W 03 SEQ SWQ SEQ	1988	

MOUNT AYR

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

March 19, 2002

ENDANGERED, THREATENED AND RARE SPECIES,
HIGH QUALITY NATURAL COMMUNITIES, AND SIGNIFICANT NATURAL AREAS DOCUMENTED
FROM THE CURTIS CREEK WATERSHED, JASPER & NEWTON COUNTIES, INDIANA

TYPE	SPECIES NAME	COMMON NAME	STATE	FED	LOCATION	DATE	COMMENT
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	T29NR07W 20 SEQ SWQ	1981	
Reptile	EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	T29NR07W 3.5 MI SW OF PARR	NO D	
Reptile	THAMNOPHIS PROXIMUS	WESTERN RIBBON SNAKE	SSC	**	T29NR07W 07	NO D	

PARR

TYPE	SPECIES NAME	COMMON NAME	STATE	FED	LOCATION	DATE	COMMENT
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	T01NR01E 4 MI S OF LIBERTY	1960	

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 5:

Endangered, Threatened, and Rare Species List,
Jasper and Newton Counties

November 12, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM JASPER COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
AGALINIS AURICULATA	EARLEAF FOXGLOVE	SE	**	S1	G3
ANDROSACE OCCIDENTALIS	WESTERN ROCKJASMINE	ST	**	S2	G5
ARABIS GLABRA	TOWER-MUSTARD	ST	**	S2	G5
ARALIA HISPIDA	BRISTLY SARSAPARILLA	SE	**	S1	G5
ARISTIDA INTERMEDIA	SLIM-SPIKE THREE-AWN GRASS	SR	**	S2	G?
ARMORACIA AQUATICA	LAKE CRESS	SE	**	S1	G4?
ASTER SERICEUS	WESTERN SILVERY ASTER	SR	**	S2	G5
CIRSIUM HILLII	HILL'S THISTLE	SE	**	S1	G3
CORYDALIS SEMPERVIRENS	PALE CORYDALIS	SE	**	S1	G4G5
CYPERUS DENTATUS	TOOTHED SEDGE	SE	**	S1	G4
DIERVILLA LONICERA	NORTHERN BUSH-HONEYSUCKLE	SR	**	S2	G5
DROSERA INTERMEDIA	SPOON-LEAVED SUNDEW	SR	**	S2	G5
ELEOCHARIS MELANOCARPA	BLACK-FRUITED SPIKE-RUSH	ST	**	S2	G4
ELEOCHARIS MICROCARPA	SMALL-FRUITED SPIKE-RUSH	SE	**	S1	G5
ELEOCHARIS ROBBINSII	ROBBINS SPIKERUSH	SR	**	S2	G4G5
FIMBRISTYLIS PUBERULA	CAROLINA FIMBRY	SE	**	S1	G5
GENTIANA PUBERULENTA	DOWNY GENTIAN	ST	**	S2	G4G5
HYPERICUM ADPRESSUM	CREEPING ST. JOHN'S-WORT	SE	**	S1	G2G3
JUNCUS PELOCARPUS	BROWN-FRUITED RUSH	ST	**	S2	G5
LIATRIS PYCNOSTACHYA	CATTAIL GAY-FEATHER	ST	**	S2	G5
LINUM INTERCURSUM	SANDPLAIN FLAX	SE	**	S1	G4
LINUM SULCATUM	GROOVED YELLOW FLAX	SR	**	S2	G5
LUDWIGIA SPHAEROCARPA	GLOBE-FRUITED FALSE-LOOSESTRIFE	SE	**	S1	G5
LYCOPODIELLA INUNDATA	NORTHERN BOG CLUBMOSS	SE	**	S1	G5
LYCOPODIUM HICKEYI	HICKEY'S CLUBMOSS	SR	**	S2	G5
LYCOPODIUM TRISTACHYUM	DEEP-ROOT CLUBMOSS	ST	**	S2	G5
LYCOPUS AMPLECTENS	SESSILE-LEAVED BUGLEWEED	SE	**	S1	G5
MYRIOPHYLLUM PINNATUM	CUTLEAF WATER-MILFOIL	SE	**	S1	G5
PANICUM BOREALE	NORTHERN WITCHGRASS	SR	**	S2	G5
PANICUM LEIBERGII	LEIBERG'S WITCHGRASS	ST	**	S2	G5
PANICUM VERRUCOSUM	WARTY PANIC-GRASS	ST	**	S2	G4
PERIDERIDIA AMERICANA	EASTERN EULOPHUS	SE	**	S1	G4
PLATANTHERA CILIARIS	YELLOW-FRINGE ORCHIS	SE	**	S1	G5
POLYGONUM CAREYI	CAREY'S SMARTWEED	ST	**	S2	G4
POLYGONUM HYDROPIPEROIDES VAR OPELOUSANUM	NORTHEASTERN SMARTWEED	ST	**	S2	G5
POLYTAENIA NUTTALLII	PRAIRIE PARSLEY	SE	**	S1	G5
PRENANTHES ASPERA	ROUGH RATTLESNAKE-ROOT	SR	**	S2	G4?
PSILOCARYA SCIRPOIDES	LONG-BEAKED BALDRUSH	ST	**	S2	G4
RHYNCHOSPORA GLOBULARIS VAR RECOGNITA	GLOBE BEAKED-RUSH	SE	**	S1	G5T5?
RHYNCHOSPORA MACROSTACHYA	TALL BEAKED-RUSH	SR	**	S2	G4
SABATIA CAMPANULATA	SLENDER MARSH PINK	SX	**	SX	G5

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM JASPER COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
SCIRPUS PURSHIANUS	WEAKSTALK BULRUSH	SE	**	S1	G4G5
SCIRPUS TORREYI	TORREY'S BULRUSH	SE	**	S1	G5?
SCLERIA RETICULARIS	RETICULATED NUTRUSH	ST	**	S2	G3G4
TALINUM RUGOSPERMUM	PRAIRIE FAME-FLOWER	ST	**	S2	G3?
TRICHOSTEMA DICHOTOMUM	FORKED BLUECURL	SR	**	S2	G5
UTRICULARIA RADIATA	SMALL SWOLLEN BLADDERWORT	SE	**	S1	G4
UTRICULARIA SUBULATA	ZIGZAG BLADDERWORT	ST	**	S2	G5
VIOLA PEDATIFIDA	PRAIRIE VIOLET	ST	**	S2	G5
VIOLA PRIMULIFOLIA	PRIMROSE-LEAF VIOLET	SR	**	S2	G5
XYRIS DIFFORMIS	CAROLINA YELLOW-EYED GRASS	ST	**	S2	G5
ARTHROPODA: INSECTA: LEPIDOPTERA (BUTTERFLIES; SKIPPERS)					
ATRYTONOPSIS HIANNA	DUSTED SKIPPER	ST	**	S2S3	G4G5
CALLOPHRYS IRUS	FROSTED ELFIN	SR	**	S2	G3G4
ERYNNIS MARTIALIS	MOTTLED DUSKYWING	ST	**	S3	G4
EUCHLOE OLYMPIA	OLYMPIA MARBLEWING	ST	**	S2	G4
HESPERIA METEA	COBWEB SKIPPER	ST	**	S2S3	G4G5
HESPERIA OTTOE	OTTOE SKIPPER	SE	**	S1	G3G4
HESPERIA SASSACUS	INDIAN SKIPPER	SR	**	S3	G5
PROBLEMA BYSSUS	BUNCHGRASS SKIPPER	SR	**	S2	G3G4
FISH					
MOXOSTOMA VALENCIENNESI	GREATER REDHORSE	SE	**	S2	G3
AMPHIBIANS					
AMBYSTOMA LATERALE	BLUE-SPOTTED SALAMANDER	SSC	**	S2	G5
RANA AREOLATA CIRCULOSA	NORTHERN CRAWFISH FROG	SE	**	S2	G4T4
RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
REPTILES					
CLEMMYS GUTTATA	SPOTTED TURTLE	SE	**	S2	G5
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
KINOSTERNON SUBRUBRUM	EASTERN MUD TURTLE	SE	**	S2	G5
LIOCHLOROPHIS VERNALIS	SMOOTH GREEN SNAKE	SE	**	S2	G5
OPHISAURUS ATTENUATUS	SLENDER GLASS LIZARD	**	**	S2	G5
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
TERRAPENE ORNATA	ORNATE BOX TURTLE	SE	**	S2	G5
THAMNOPHIS PROXIMUS	WESTERN RIBBON SNAKE	SSC	**	S3	G5
BIRDS					
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
BARTRAMIA LONGICAUDA	UPLAND SANDPIPER	SE	**	S3B	G5
BUTEO LINEATUS	RED-SHOULDERED HAWK	SSC	**	S3	G5

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM JASPER COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
CIRCUS CYANEUS	NORTHERN HARRIER	SE	**	S2	G5
CISTOTHORUS PALUSTRIS	MARSH WREN	SE	**	S3B,SZN	G5
CISTOTHORUS PLATENSIS	SEDGE WREN	SE	**	S3B,SZN	G5
GRUS CANADENSIS	SANDHILL CRANE	SE	**	S2B,S1N	G5
IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3B	G5
LANIUS LUDOVICIANUS	LOGGERHEAD SHRIKE	SE	**	S3B,SZN	G5
RALLUS LIMICOLA	VIRGINIA RAIL	SSC	**	S3B,SZN	G5
VERMIVORA CHRYSOPTERA	GOLDEN-WINGED WARBLER	SE	**	S1B	G4
MAMMALS					
GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	S2	G5
MYOTIS SODALIS	INDIANA BAT OR SOCIAL MYOTIS	SE	LE	S1	G2
REITHRODONTOMYS MEGALOTIS	WESTERN HARVEST MOUSE	SSC	**	S2	G5
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
PRAIRIE - MESIC	MESIC PRAIRIE	SG	**	S2	G2
PRAIRIE - SAND DRY-MESIC	DRY-MESIC SAND PRAIRIE	SG	**	S3	G3
PRAIRIE - SAND WET	WET SAND PRAIRIE	SG	**	S3	G3
PRAIRIE - SAND WET-MESIC	WET-MESIC SAND PRAIRIE	SG	**	S2	G1?
SAVANNA - SAND DRY	DRY SAND SAVANNA	SG	**	S2	G2?
SAVANNA - SAND DRY-MESIC	DRY-MESIC SAND SAVANNA	SG	**	S2S3	G2?
WETLAND - MARSH	MARSH	SG	**	S4	GU
WETLAND - MEADOW SEDGE	SEDGE MEADOW	SG	**	S1	G3?
OTHER FEATURE OF SIGNIFICANCE					
MIGRATORY BIRD CONCENTRATION SITE	MIGRATORY BIRD CONCENTRATION SITE	SG	**		

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

November 16, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM NEWTON COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ANDROSACE OCCIDENTALIS	WESTERN ROCKJASMINE	ST	**	S2	G5
ARISTIDA INTERMEDIA	SLIM-SPIKE THREE-AWN GRASS	SR	**	S2	G?
ARISTIDA TUBERCULOSA	SEABEACH NEEDLEGRASS	SR	**	S2	G5
ARMORACIA AQUATICA	LAKE CRESS	SE	**	S1	G4?
ASTER SERICEUS	WESTERN SILVERY ASTER	SR	**	S2	G5
AZOLLA CAROLINIANA	CAROLINA MOSQUITO-FERN	ST	**	S2	G5
CAREX AUREA	GOLDEN-FRUITED SEDGE	SR	**	S2	G5
CAREX CRAWEI	CRAWE SEDGE	ST	**	S2	G5
CAREX CUMULATA	CLUSTERED SEDGE	SE	**	S1	G4?
CAREX GARBERI	ELK SEDGE	ST	**	S2	G4
CIRSIUM HILLII	HILL'S THISTLE	SE	**	S1	G3
CORYDALIS SEMPERVIRENS	PALE CORYDALIS	SE	**	S1	G4G5
CYPERUS HOUGHTONII	HOUGHTON'S NUTSEDGE	SR	**	S2	G4?
ECHINODORUS PARVULUS	LITTLE BUR-HEAD	SE	**	S1	G3
GENTIANA PUBERULENTA	DOWNY GENTIAN	ST	**	S2	G4G5
HYMENOPAPPUS SCABIOSAEUS	CAROLINA WOOLLYWHITE	SE	**	S1	G4G5
HYPERICUM GYMNANTHUM		SE	**	S1	G4
LACTUCA LUDOVICIANA	WESTERN LETTUCE	SX	**	SX	G4G5
LIATRIS PYCNOSTACHYA	CATTAIL GAY-FEATHER	ST	**	S2	G5
LUDWIGIA SPHAEROCARPA	GLOBE-FRUITED FALSE-LOOSESTRIFE	SE	**	S1	G5
PANICUM LEIBERGII	LEIBERG'S WITCHGRASS	ST	**	S2	G5
PANICUM VERRUCOSUM	WARTY PANIC-GRASS	ST	**	S2	G4
PERIDERIDIA AMERICANA	EASTERN EULOPHUS	SE	**	S1	G4
PLATANTHERA CILIARIS	YELLOW-FRINGE ORCHIS	SE	**	S1	G5
POA WOLFII	WOLF BLUEGRASS	SR	**	S2	G4
POLYGONELLA ARTICULATA	EASTERN JOINTWEED	SR	**	S2	G5
POLYGONUM CAREYI	CAREY'S SMARTWEED	ST	**	S2	G4
POLYGONUM HYDROPIPEROIDES VAR OPELOUSANUM	NORTHEASTERN SMARTWEED	ST	**	S2	G5
PRENANTHES ASPERA	ROUGH RATTLESNAKE-ROOT	SR	**	S2	G4?
SCLERIA RETICULARIS	RETICULATED NUTRUSH	ST	**	S2	G3G4
SPIRANTHES MAGNICAMPORUM	GREAT PLAINS LADIES'-TRESSES	SE	**	S1	G4
STENANTHIUM GRAMINEUM	EASTERN FEATHERBELLS	SE	**	S1	G4G5
TALINUM RUGOSPERMUM	PRAIRIE FAME-FLOWER	ST	**	S2	G3?
VIOLA PEDATIFIDA	PRAIRIE VIOLET	ST	**	S2	G5
VIOLA PRIMULIFOLIA	PRIMROSE-LEAF VIOLET	SR	**	S2	G5
ARTHROPODA: INSECTA: HOMOPTERA (CICADAS; HOPPERS; SCALES; APHIDS)					
MESAMIA STRAMINEA	HELIANTHUS LEAFHOPPER	WL	**	S?	G?
PRAIRIANA KANSANA	A LEAFHOPPER	ST	**	S1	G?
ARTHROPODA: INSECTA: LEPIDOPTERA (BUTTERFLIES; SKIPPERS)					

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM NEWTON COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
ATRYTONOPSIS HIANNA	DUSTED SKIPPER	ST	**	S2S3	G4G5
BOLORIA SELENE MYRINA	SILVER-BORDERED FRITILLARY	**	**	S2S3	G5T5
BOLORIA SELENE NEBRASKENSIS	NEBRASKA FRITILLARY	**	**	S1?	G?
ERYNNIS MARTIALIS	MOTTLED DUSKYWING	ST	**	S3	G4
EUCHLOE OLYMPIA	OLYMPIA MARBLEWING	ST	**	S2	G4
EUPHYES BIMACULA	TWO-SPOTTED SKIPPER	SR	**	S2	G4
HESPERIA METEA	COBWEB SKIPPER	ST	**	S2S3	G4G5
HESPERIA SASSACUS	INDIAN SKIPPER	SR	**	S3	G5
POANES VIATOR VIATOR	BIG BROAD-WINGED SKIPPER	SR	**	S2	G5T4
PROBLEMA BYSSUS	BUNCHGRASS SKIPPER	SR	**	S2	G3G4
SPEYERIA IDALIA	REGAL FRITILLARY	SE	**	S1	G3
ARTHROPODA: INSECTA: LEPIDOPTERA (MOTHS)					
SCHINIA GLORIOSA	GLORIUS FLOWER MOTH	WL	**	SU	G4
AMPHIBIANS					
RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
REPTILES					
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
KINOSTERNON SUBRUBRUM	EASTERN MUD TURTLE	SE	**	S2	G5
LIOCHLOROPHIS VERNALIS	SMOOTH GREEN SNAKE	SE	**	S2	G5
OPHISAURUS ATTENUATUS	SLENDER GLASS LIZARD	**	**	S2	G5
TERRAPENE ORNATA	ORNATE BOX TURTLE	SE	**	S2	G5
THAMNOPHIS PROXIMUS	WESTERN RIBBON SNAKE	SSC	**	S3	G5
BIRDS					
ACCIPITER COOPERII	COOPER'S HAWK	**	**	S3B,SZN	G5
AMMODRAMUS HENSLOWII	HENSLOW'S SPARROW	SE	**	S3B,SZN	G4
ANAS CLYPEATA	NORTHERN SHOVELER	**	**	SHB,SAN	G5
ARDEA ALBA	GREAT EGRET	SSC	**	S1B,SZN	G5
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
ASIO OTUS	LONG-EARED OWL	**	**	S2	G5
BARTRAMIA LONGICAUDA	UPLAND SANDPIPER	SE	**	S3B	G5
BOTAURUS LENTIGINOSUS	AMERICAN BITTERN	SE	**	S2B	G4
BUTEO LINEATUS	RED-SHOULDERED HAWK	SSC	**	S3	G5
CERTHIA AMERICANA	BROWN CREEPER	**	**	S2B,SZN	G5
CHLIDONIAS NIGER	BLACK TERN	SE	**	S1B,SZN	G4
CIRCUS CYANEUS	NORTHERN HARRIER	SE	**	S2	G5
CISTOTHORUS PALUSTRIS	MARSH WREN	SE	**	S3B,SZN	G5
CISTOTHORUS PLATENSIS	SEDGE WREN	SE	**	S3B,SZN	G5
DENDROICA CERULEA	CERULEAN WARBLER	SSC	**	S3B	G4
EMPIDONAX MINIMUS	LEAST FLYCATCHER	**	**	S3B	G5

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM NEWTON COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
GRUS CANADENSIS	SANDHILL CRANE	SE	**	S2B,S1N	G5
IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3B	G5
LANIUS LUDOVICIANUS	LOGGERHEAD SHRIKE	SE	**	S3B,SZN	G5
MNIOTILTA VARIA	BLACK-AND-WHITE WARBLER	SSC	**	S1S2B	G5
NYCTICORAX NYCTICORAX	BLACK-CROWNED NIGHT-HERON	SE	**	S1B,SAN	G5
RALLUS ELEGANS	KING RAIL	SE	**	S1B,SZN	G4G5
RALLUS LIMICOLA	VIRGINIA RAIL	SSC	**	S3B,SZN	G5
STURNELLA NEGLECTA	WESTERN MEADOWLARK	SSC	**	S2B	G5
VERMIVORA CHRYSOPTERA	GOLDEN-WINGED WARBLER	SE	**	S1B	G4
WILSONIA CANADENSIS	CANADA WARBLER	**	**	S2B	G5
XANTHOCEPHALUS XANTHOCEPHALUS	YELLOW-HEADED BLACKBIRD	SE	**	S1B	G5
MAMMALS					
GEOMYS BURSARIUS	PLAINS POCKET GOPHER	SSC	**	S2	G5
LUTRA CANADENSIS	NORTHERN RIVER OTTER	SE	**	S?	G5
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
REITHRODONTOMYS MEGALOTIS	WESTERN HARVEST MOUSE	SSC	**	S2	G5
SPERMOPHILUS FRANKLINII	FRANKLIN'S GROUND SQUIRREL	SE	**	S2	G5
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
FOREST - FLATWOODS SAND	SAND FLATWOODS	SG	**	S1	G2?
PRAIRIE - DRY-MESIC	DRY-MESIC PRAIRIE	SG	**	S2	G3
PRAIRIE - MESIC	MESIC PRAIRIE	SG	**	S2	G2
PRAIRIE - SAND DRY	DRY SAND PRAIRIE	SG	**	S2	G3
PRAIRIE - SAND DRY-MESIC	DRY-MESIC SAND PRAIRIE	SG	**	S3	G3
PRAIRIE - SAND MESIC	MESIC SAND PRAIRIE	SG	**		
PRAIRIE - SAND WET	WET SAND PRAIRIE	SG	**	S3	G3
PRAIRIE - SAND WET-MESIC	WET-MESIC SAND PRAIRIE	SG	**	S2	G1?
SAVANNA - SAND DRY	DRY SAND SAVANNA	SG	**	S2	G2?
SAVANNA - SAND DRY-MESIC	DRY-MESIC SAND SAVANNA	SG	**	S2S3	G2?
WETLAND - MEADOW SEDGE	SEDGE MEADOW	SG	**	S1	G3?

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 6:

Stream Sampling Laboratory Data

MOUTH SUBWATERSHED WATER QUALITY SAMPLING RESULTS.
TABLE 6.1.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	22.5	--
Dissolved Oxygen (mg/L)	7.62	--
Dissolved Oxygen Percent Saturation (%)	87.5	--
Conductivity (μmhos)	600	--
pH	7.9	--
Alkalinity (mg/L)	208	--
Turbidity (NTU)	5.5	--
Total Kjeldahl Nitrogen (mg/L)	0.931	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.031	0.018 mg/L
Nitrate-Nitrogen (mg/L)	2.92	0.022 mg/L
Total Phosphorus (mg/L)	0.069	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.014	0.010 mg/L
Total Suspended Solids (mg/L)	11.00	--
E. coli (col/100 mL)	2400	--

TABLE 6.1.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	21.5	--
Dissolved Oxygen (mg/L)	5.39	--
Dissolved Oxygen Percent Saturation (%)	60.5	--
Conductivity (μmhos)	NA	--
pH	7.45	--
Alkalinity (mg/L)	125	--
Turbidity (NTU)	26	--
Total Kjeldahl Nitrogen (mg/L)	1.843	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.045	0.018 mg/L
Nitrate-Nitrogen (mg/L)	6.74	0.022 mg/L
Total Phosphorus (mg/L)	0.217	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.062	0.010 mg/L
Total Suspended Solids (mg/L)	98.40	--
E. coli (col/100 mL)	7300	--

TABLE 6.1.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	11.6	--
Dissolved Oxygen (mg/L)	6.42	--
Dissolved Oxygen Percent Saturation (%)	56.7	--
Conductivity (μmhos)	252.4	--
pH	7.18	--
Alkalinity (mg/L)	93	--
Turbidity (NTU)	34	--
Total Kjeldahl Nitrogen (mg/L)	2.009	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.462	0.018 mg/L
Nitrate-Nitrogen (mg/L)	5.587	0.022 mg/L
Total Phosphorus (mg/L)	0.353	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.169	0.010 mg/L
Total Suspended Solids (mg/L)	30.4	--
E. coli (col/100 mL)	5800	--

YEOMAN DITCH SUBWATERSHED WATER QUALITY SAMPLING RESULTS.

TABLE 6.2.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (°C)	23	--
Dissolved Oxygen (mg/L)	7.84	--
Dissolved Oxygen Percent Saturation (%)	91.4	--
Conductivity (μmhos)	800	--
pH	8	--
Alkalinity (mg/L)	250	--
Turbidity (NTU)	4.3	--
Total Kjeldahl Nitrogen (mg/L)	0.740	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.102	0.018 mg/L
Nitrate-Nitrogen (mg/L)	5.27	0.022 mg/L
Total Phosphorus (mg/L)	0.128	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.044	0.010 mg/L
Total Suspended Solids (mg/L)	0.25	--
E. coli (col/100 mL)	440	--

TABLE 6.2.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (°C)	21.2	--
Dissolved Oxygen (mg/L)	4.78	--
Dissolved Oxygen Percent Saturation (%)	53.6	--
Conductivity (μmhos)	NA	--
pH	7.45	--
Alkalinity (mg/L)	148	--
Turbidity (NTU)	22	--
Total Kjeldahl Nitrogen (mg/L)	1.619	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.132	0.018 mg/L
Nitrate-Nitrogen (mg/L)	6.23	0.022 mg/L
Total Phosphorus (mg/L)	0.304	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.114	0.010 mg/L
Total Suspended Solids (mg/L)	66.80	--
E. coli (col/100 mL)	2900	--

TABLE 6.2.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (°C)	11.1	--
Dissolved Oxygen (mg/L)	5.5	--
Dissolved Oxygen Percent Saturation (%)	51.2	--
Conductivity (μmhos)	342.2	--
pH	6.95	--
Alkalinity (mg/L)	123	--
Turbidity (NTU)	16.5	--
Total Kjeldahl Nitrogen (mg/L)	2.024	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.477	0.018 mg/L
Nitrate-Nitrogen (mg/L)	8.381	0.022 mg/L
Total Phosphorus (mg/L)	0.303	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.183	0.010 mg/L
Total Suspended Solids (mg/L)	11.6	--
E. coli (col/100 mL)	840	--

GOLF COURSE SUBWATERSHED WATER QUALITY SAMPLING RESULTS.

TABLE 6.3.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	24.3	--
Dissolved Oxygen (mg/L)	8.43	--
Dissolved Oxygen Percent Saturation (%)	99.6	--
Conductivity (μmhos)	600	--
Ph	8	--
Alkalinity (mg/L)	197	--
Turbidity (NTU)	4.5	--
Total Kjeldahl Nitrogen (mg/L)	0.849	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.206	0.018 mg/L
Nitrate-Nitrogen (mg/L)	3.02	0.022 mg/L
Total Phosphorus (mg/L)	0.090	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.011	0.010 mg/L
Total Suspended Solids (mg/L)	3.14	--
E. coli (col/100 mL)	730	--

TABLE 6.3.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	21.4	--
Dissolved Oxygen (mg/L)	5.69	--
Dissolved Oxygen Percent Saturation (%)	63.8	--
Conductivity (μmhos)	NA	--
pH	7.4	--
Alkalinity (mg/L)	131	--
Turbidity (NTU)	20	--
Total Kjeldahl Nitrogen (mg/L)	1.593	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.035	0.018 mg/L
Nitrate-Nitrogen (mg/L)	6.66	0.022 mg/L
Total Phosphorus (mg/L)	0.172	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.061	0.010 mg/L
Total Suspended Solids (mg/L)	64.50	--
E. coli (col/100 mL)	5500	--

TABLE 6.3.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	12	--
Dissolved Oxygen (mg/L)	6.68	--
Dissolved Oxygen Percent Saturation (%)	61.9	--
Conductivity (μmhos)	286.8	--
pH	6.95	--
Alkalinity (mg/L)	108	--
Turbidity (NTU)	23	--
Total Kjeldahl Nitrogen (mg/L)	1.553	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.363	0.018 mg/L
Nitrate-Nitrogen (mg/L)	5.661	0.022 mg/L
Total Phosphorus (mg/L)		0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.122	0.010 mg/L
Total Suspended Solids (mg/L)	31.6	--
E. coli (col/100 mL)	2100	--

STATE ROAD 114 SUBWATERSHED WATER QUALITY SAMPLING RESULTS.

TABLE 6.4.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	24.2	--
Dissolved Oxygen (mg/L)	5.53	--
Dissolved Oxygen Percent Saturation (%)	65.9	--
Conductivity (μmhos)	780	--
Ph	7.85	--
Alkalinity (mg/L)	272	--
Turbidity (NTU)	12	--
Total Kjeldahl Nitrogen (mg/L)	14.193	0.230 mg/L
Ammonia-Nitrogen (mg/L)	9.905	0.018 mg/L
Nitrate-Nitrogen (mg/L)	1.86	0.022 mg/L
Total Phosphorus (mg/L)	0.434	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.058	0.010 mg/L
Total Suspended Solids (mg/L)	18.00	--
E. coli (col/100 mL)	2400	--

TABLE 6.4.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	21.7	--
Dissolved Oxygen (mg/L)	5.37	--
Dissolved Oxygen Percent Saturation (%)	61.1	--
Conductivity (μmhos)	NA	--
pH	7.4	--
Alkalinity (mg/L)	134	--
Turbidity (NTU)	17	--
Total Kjeldahl Nitrogen (mg/L)	1.510	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.033	0.018 mg/L
Nitrate-Nitrogen (mg/L)	6.43	0.022 mg/L
Total Phosphorus (mg/L)	0.152	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.065	0.010 mg/L
Total Suspended Solids (mg/L)	49.50	--
E. coli (col/100 mL)	4600	--

TABLE 6.4.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	12.2	--
Dissolved Oxygen (mg/L)	6.52	--
Dissolved Oxygen Percent Saturation (%)	59.9	--
Conductivity (μmhos)	295.6	--
pH	7.15	--
Alkalinity (mg/L)	112	--
Turbidity (NTU)	22	--
Total Kjeldahl Nitrogen (mg/L)	1.949	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.318	0.018 mg/L
Nitrate-Nitrogen (mg/L)	5.628	0.022 mg/L
Total Phosphorus (mg/L)	0.288	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.177	0.010 mg/L
Total Suspended Solids (mg/L)	31.87	--
E. coli (col/100 mL)	2500	--

LONG DITCH SUBWATERSHED WATER QUALITY SAMPLING RESULTS.

TABLE 6.5.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	18.1	--
Dissolved Oxygen (mg/L)	6.94	--
Dissolved Oxygen Percent Saturation (%)	73.4	--
Conductivity (μmhos)	600	--
Ph	7.85	--
Alkalinity (mg/L)	232	--
Turbidity (NTU)	6.5	--
Total Kjeldahl Nitrogen (mg/L)	0.328	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.145	0.018 mg/L
Nitrate-Nitrogen (mg/L)	9.99	0.022 mg/L
Total Phosphorus (mg/L)	0.137	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.065	0.010 mg/L
Total Suspended Solids (mg/L)	2.25	--
E. coli (col/100 mL)	1100	--

TABLE 6.5.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	21.8	--
Dissolved Oxygen (mg/L)	5.34	--
Dissolved Oxygen Percent Saturation (%)	61.7	--
Conductivity (μmhos)	NA	--
pH	7.4	--
Alkalinity (mg/L)	150	--
Turbidity (NTU)	12	--
Total Kjeldahl Nitrogen (mg/L)	1.047	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.018	0.018 mg/L
Nitrate-Nitrogen (mg/L)	8.21	0.022 mg/L
Total Phosphorus (mg/L)	0.190	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.117	0.010 mg/L
Total Suspended Solids (mg/L)	23.00	--
E. coli (col/100 mL)	12000	--

TABLE 6.5.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	13	--
Dissolved Oxygen (mg/L)	8.07	--
Dissolved Oxygen Percent Saturation (%)	71.6	--
Conductivity (μmhos)	526	--
pH	7.4	--
Alkalinity (mg/L)	145.5	--
Turbidity (NTU)	42.5	--
Total Kjeldahl Nitrogen (mg/L)	0.834	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.149	0.018 mg/L
Nitrate-Nitrogen (mg/L)	11.212	0.022 mg/L
Total Phosphorus (mg/L)	0.229	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.103	0.010 mg/L
Total Suspended Solids (mg/L)	17.14	--
E. coli (col/100 mL)	1700	--

COUNTY ROAD 100 SOUTH SUBWATERSHED WATER QUALITY SAMPLING RESULTS.

TABLE 6.6.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	21.9	--
Dissolved Oxygen (mg/L)	2.16	--
Dissolved Oxygen Percent Saturation (%)	24.7	--
Conductivity (μmhos)	580	--
Ph	7.7	--
Alkalinity (mg/L)	216	--
Turbidity (NTU)	3.3	--
Total Kjeldahl Nitrogen (mg/L)	4.196	0.230 mg/L
Ammonia-Nitrogen (mg/L)	3.024	0.018 mg/L
Nitrate-Nitrogen (mg/L)	1.72	0.022 mg/L
Total Phosphorus (mg/L)	0.222	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.074	0.010 mg/L
Total Suspended Solids (mg/L)	3.75	--
E. coli (col/100 mL)	260	--

TABLE 6.6.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	25.2	--
Dissolved Oxygen (mg/L)	6.95	--
Dissolved Oxygen Percent Saturation (%)	84.2	--
Conductivity (μmhos)	NA	--
pH	7.5	--
Alkalinity (mg/L)	151	--
Turbidity (NTU)	7	--
Total Kjeldahl Nitrogen (mg/L)	1.115	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.048	0.018 mg/L
Nitrate-Nitrogen (mg/L)	4.94	0.022 mg/L
Total Phosphorus (mg/L)	0.103	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.037	0.010 mg/L
Total Suspended Solids (mg/L)	31.00	--
E. coli (col/100 mL)	830	--

TABLE 6.6.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	14.5	--
Dissolved Oxygen (mg/L)	6.56	--
Dissolved Oxygen Percent Saturation (%)	64.6	--
Conductivity (μmhos)	354.5	--
pH	7.13	--
Alkalinity (mg/L)	130	--
Turbidity (NTU)	17	--
Total Kjeldahl Nitrogen (mg/L)	1.5	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.36	0.018 mg/L
Nitrate-Nitrogen (mg/L)	4.987	0.022 mg/L
Total Phosphorus (mg/L)	0.222	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.076	0.010 mg/L
Total Suspended Solids (mg/L)	13.25	--
E. coli (col/100 mL)	780	--

ELIJAH DITCH SUBWATERSHED WATER QUALITY SAMPLING RESULTS.

TABLE 6.7.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	22.9	--
Dissolved Oxygen (mg/L)	7.91	--
Dissolved Oxygen Percent Saturation (%)	92.4	--
Conductivity (μmhos)	580	--
Ph	7.9	--
Alkalinity (mg/L)	212	--
Turbidity (NTU)	4	--
Total Kjeldahl Nitrogen (mg/L)	0.614	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.108	0.018 mg/L
Nitrate-Nitrogen (mg/L)	1.19	0.022 mg/L
Total Phosphorus (mg/L)	0.125	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.017	0.010 mg/L
Total Suspended Solids (mg/L)	0.75	--
E. coli (col/100 mL)	280	--

TABLE 6.7.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	24.6	--
Dissolved Oxygen (mg/L)	5.35	--
Dissolved Oxygen Percent Saturation (%)	63.3	--
Conductivity (μmhos)	NA	--
pH	7.5	--
Alkalinity (mg/L)	170	--
Turbidity (NTU)	4	--
Total Kjeldahl Nitrogen (mg/L)	0.968	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.018	0.018 mg/L
Nitrate-Nitrogen (mg/L)	7.15	0.022 mg/L
Total Phosphorus (mg/L)	0.072	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.028	0.010 mg/L
Total Suspended Solids (mg/L)	10.00	--
E. coli (col/100 mL)	780	--

TABLE 6.7.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	14.2	--
Dissolved Oxygen (mg/L)	6.13	--
Dissolved Oxygen Percent Saturation (%)	60.7	--
Conductivity (μmhos)	368	--
pH	7.06	--
Alkalinity (mg/L)	136.5	--
Turbidity (NTU)	15	--
Total Kjeldahl Nitrogen (mg/L)	1.626	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.673	0.018 mg/L
Nitrate-Nitrogen (mg/L)	3.559	0.022 mg/L
Total Phosphorus (mg/L)	0.121	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.007	0.010 mg/L
Total Suspended Solids (mg/L)	6.25	--
E. coli (col/100 mL)	240	--

KOSTA DITCH SUBWATERSHED WATER QUALITY SAMPLING RESULTS.

TABLE 6.8.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	20.8	--
Dissolved Oxygen (mg/L)	6.66	--
Dissolved Oxygen Percent Saturation (%)	74.4	--
Conductivity (μmhos)	570	--
Ph	7.85	--
Alkalinity (mg/L)	182	--
Turbidity (NTU)	2.6	--
Total Kjeldahl Nitrogen (mg/L)	0.906	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.128	0.018 mg/L
Nitrate-Nitrogen (mg/L)	3.17	0.022 mg/L
Total Phosphorus (mg/L)	0.122	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.028	0.010 mg/L
Total Suspended Solids (mg/L)	3.87	--
E. coli (col/100 mL)	3400	--

TABLE 6.8.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	23.4	--
Dissolved Oxygen (mg/L)	6.34	--
Dissolved Oxygen Percent Saturation (%)	74.6	--
Conductivity (μmhos)	NA	--
pH	7.5	--
Alkalinity (mg/L)	123	--
Turbidity (NTU)	5	--
Total Kjeldahl Nitrogen (mg/L)	1.452	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.129	0.018 mg/L
Nitrate-Nitrogen (mg/L)	3.59	0.022 mg/L
Total Phosphorus (mg/L)	0.142	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.069	0.010 mg/L
Total Suspended Solids (mg/L)	11.60	--
E. coli (col/100 mL)	2200	--

TABLE 6.8.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	14.2	--
Dissolved Oxygen (mg/L)	8	--
Dissolved Oxygen Percent Saturation (%)	78	--
Conductivity (μmhos)	308.8	--
pH	6.94	--
Alkalinity (mg/L)	98	--
Turbidity (NTU)	10.5	--
Total Kjeldahl Nitrogen (mg/L)	1.366	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.053	0.018 mg/L
Nitrate-Nitrogen (mg/L)	5.381	0.022 mg/L
Total Phosphorus (mg/L)	0.141	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.063	0.010 mg/L
Total Suspended Solids (mg/L)	7.43	--
E. coli (col/100 mL)	290	--

HEADWATERS SUBWATERSHED WATER QUALITY SAMPLING RESULTS.
TABLE 6.9.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	23.2	--
Dissolved Oxygen (mg/L)	4.97	--
Dissolved Oxygen Percent Saturation (%)	59.3	--
Conductivity (μmhos)	550	--
Ph	7.8	--
Alkalinity (mg/L)	191	--
Turbidity (NTU)	1.8	--
Total Kjeldahl Nitrogen (mg/L)	3.173	0.230 mg/L
Ammonia-Nitrogen (mg/L)	2.414	0.018 mg/L
Nitrate-Nitrogen (mg/L)	1.49	0.022 mg/L
Total Phosphorus (mg/L)	0.222	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.140	0.010 mg/L
Total Suspended Solids (mg/L)	0.75	--
E. coli (col/100 mL)	330	--

TABLE 6.9.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	24.6	--
Dissolved Oxygen (mg/L)	7.9	--
Dissolved Oxygen Percent Saturation (%)	92.7	--
Conductivity (μmhos)	NA	--
pH	7.6	--
Alkalinity (mg/L)	170	--
Turbidity (NTU)	2	--
Total Kjeldahl Nitrogen (mg/L)	0.877	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.018	0.018 mg/L
Nitrate-Nitrogen (mg/L)	3.28	0.022 mg/L
Total Phosphorus (mg/L)	0.052	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.022	0.010 mg/L
Total Suspended Solids (mg/L)	9.75	--
E. coli (col/100 mL)	420	--

TABLE 6.9.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	13.3	--
Dissolved Oxygen (mg/L)	5.88	--
Dissolved Oxygen Percent Saturation (%)	58.2	--
Conductivity (μmhos)	522	--
pH	7.22	--
Alkalinity (mg/L)	149	--
Turbidity (NTU)	13.5	--
Total Kjeldahl Nitrogen (mg/L)	1.327	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.328	0.018 mg/L
Nitrate-Nitrogen (mg/L)	5.548	0.022 mg/L
Total Phosphorus (mg/L)	0.266	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.092	0.010 mg/L
Total Suspended Solids (mg/L)	17.25	--
E. coli (col/100 mL)	1400	--

FAIR OAKS SUBWATERSHED WATER QUALITY SAMPLING RESULTS.

TABLE 6.10.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	25.2	--
Dissolved Oxygen (mg/L)	11.56	--
Dissolved Oxygen Percent Saturation (%)	140.5	--
Conductivity (μmhos)	550	--
Ph	8.2	--
Alkalinity (mg/L)	137	--
Turbidity (NTU)	2	--
Total Kjeldahl Nitrogen (mg/L)	0.731	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.078	0.018 mg/L
Nitrate-Nitrogen (mg/L)	8.61	0.022 mg/L
Total Phosphorus (mg/L)	0.044	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.003	0.010 mg/L
Total Suspended Solids (mg/L)	2.25	--
E. coli (col/100 mL)	84	--

TABLE 6.10.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	24.1	--
Dissolved Oxygen (mg/L)	6.76	--
Dissolved Oxygen Percent Saturation (%)	80.4	--
Conductivity (μmhos)	NA	--
pH	7.7	--
Alkalinity (mg/L)	135	--
Turbidity (NTU)	1	--
Total Kjeldahl Nitrogen (mg/L)	0.349	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.018	0.018 mg/L
Nitrate-Nitrogen (mg/L)	14.27	0.022 mg/L
Total Phosphorus (mg/L)	0.024	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.009	0.010 mg/L
Total Suspended Solids (mg/L)	2.20	--
E. coli (col/100 mL)	2900	--

TABLE 6.10.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	16	--
Dissolved Oxygen (mg/L)	7.43	--
Dissolved Oxygen Percent Saturation (%)	75.1	--
Conductivity (μmhos)	559	--
pH	7.17	--
Alkalinity (mg/L)	132	--
Turbidity (NTU)	10.5	--
Total Kjeldahl Nitrogen (mg/L)	1.136	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.172	0.018 mg/L
Nitrate-Nitrogen (mg/L)	9.864	0.022 mg/L
Total Phosphorus (mg/L)	0.135	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.003	0.010 mg/L
Total Suspended Solids (mg/L)	18.57	--
E. coli (col/100 mL)	860	--

REFERENCE (BEAVER CREEK) WATERSHED WATER QUALITY SAMPLING RESULTS.

TABLE 6.11.1. Base flow samples collected June 24-25, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	25.2	--
Dissolved Oxygen (mg/L)	7.22	--
Dissolved Oxygen Percent Saturation (%)	87.7	--
Conductivity (μmhos)	150	--
Ph	8	--
Alkalinity (mg/L)	141	--
Turbidity (NTU)	5.3	--
Total Kjeldahl Nitrogen (mg/L)	0.783	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.056	0.018 mg/L
Nitrate-Nitrogen (mg/L)	3.07	0.022 mg/L
Total Phosphorus (mg/L)	0.078	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.024	0.010 mg/L
Total Suspended Solids (mg/L)	3.80	--
E. coli (col/100 mL)	--	--

TABLE 6.11.2. Storm flow samples collected July 30, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	25.5	--
Dissolved Oxygen (mg/L)	5.97	--
Dissolved Oxygen Percent Saturation (%)	73.1	--
Conductivity (μmhos)	NA	--
pH	7.8	--
Alkalinity (mg/L)	168	--
Turbidity (NTU)	14	--
Total Kjeldahl Nitrogen (mg/L)	1.710	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.046	0.018 mg/L
Nitrate-Nitrogen (mg/L)	8.71	0.022 mg/L
Total Phosphorus (mg/L)	0.145	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.046	0.010 mg/L
Total Suspended Solids (mg/L)	50.00	--
E. coli (col/100 mL)	--	--

TABLE 6.11.3. Flood flow samples collected May 14, 2002.

Parameter	Results	Parameter Detection Limit
Temperature (◦C)	14.1	--
Dissolved Oxygen (mg/L)	7.81	--
Dissolved Oxygen Percent Saturation (%)	75.7	--
Conductivity (μmhos)	357.6	--
pH	7.06	--
Alkalinity (mg/L)	127	--
Turbidity (NTU)	18	--
Total Kjeldahl Nitrogen (mg/L)	1.539	0.230 mg/L
Ammonia-Nitrogen (mg/L)	0.125	0.018 mg/L
Nitrate-Nitrogen (mg/L)	7.799	0.022 mg/L
Total Phosphorus (mg/L)	0.199	0.010 mg/L
Soluble Reactive Phosphorus (mg/L)	0.063	0.010 mg/L
Total Suspended Solids (mg/L)	29.2	--
E. coli (col/100 mL)	--	--

APPENDIX 7:

QHEI Datasheet

STREAM: Site 1: Curtis Creek **RIVER MILE:** ______ **DATE:** 6/24/2002 **QHEI SCORE** 42

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 6

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[ ]	[x]	SAND(6)		
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[x]	[ ]	HARDPAN(4)	x	x	[ ]	[ ]	DETRITUS(3)	x	x
[ ]	[ ]	MUCK/SILT(2)			[ ]	[ ]	ARTIFIC(0)		

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [x] TILLS(1) [x] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [x] SILT-HEAVY(-2) [ ] SILT-MOD(-1) [ ] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [x] EXTENSIVE(-2) [ ] MODERATE(-1) [ ] LOW(0) [ ] NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER: **COVER SCORE** 3

TYPE (Check all that apply): [ ] UNDERCUT BANKS(1) [ ] OVERHANGING VEGETATION(1) [ ] SHALLOWS (IN SLOW WATER)(1) [ ] DEEP POOLS(2) [x] ROOTWADS(1) [ ] BOULDERS(1) [ ] OXBOWS(1) [ ] AQUATIC MACROPHYTES(1) [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE): [ ] EXTENSIVE >75%(11) [ ] MODERATE 25-75%(7) [ ] SPARSE 5-25%(3) [x] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** 9.5

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [x] LOW(2) [ ] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [ ] FAIR(3) [x] POOR(1)

CHANNELIZATION: [ ] NONE(6) [x] RECOVERED(4) [ ] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [x] HIGH(3) [x] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [ ] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [ ] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 7

River Right Looking Downstream

RIPARIAN WIDTH (per bank) — L R (per bank): L[x] R[ ] WIDE >150 ft.(4); L[ ] R[x] MODERATE 30-150 ft.(3); [ ] [ ] NARROW 15-30 ft.(2); [ ] [ ] VERY NARROW 3-15 ft.(1); [ ] [ ] NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY — L R (most predominant per bank): L[x] R[ ] FOREST, SWAMP(3); L[ ] R[x] OPEN PASTURE/ROW CROP(0); [ ] [ ] RESID.,PARK,NEW FIELD(1); [ ] [ ] FENCED PASTURE(1)

L R (per bank): [ ] [ ] URBAN OR INDUSTRIAL(0); [ ] [ ] SHRUB OR OLD FIELD(2); [ ] [ ] CONSERV. TILLAGE(1); [ ] [ ] MINING/CONSTRUCTION(0)

BANK EROSION — L R (per bank): [ ] [ ] NONE OR LITTLE(3); L[x] R[x] MODERATE(2); [ ] [ ] HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 6

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [ ] 2.4-4 ft.(4) [x] 1.2-2.4 ft.(2) [ ] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [x] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [x] MODERATE(1) [x] SLOW(1) [x] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 2

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [x] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [x] UNSTABLE (Gravel, Sand)(0) [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [x] EXTENSIVE(-1) [ ] MODERATE(0) [ ] LOW(1) [ ] NONE(2) [ ] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 6.72 **% POOL** 5 **% RIFFLE** 5 **% RUN** 90 **GRADIENT SCORE** 8

STREAM: Site 2: Yeoman Ditch **RIVER MILE:** ______ **DATE:** 6/24/2002 **QHEI SCORE** 37

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 8

TYPE			POOL	RIFFLE	TYPE			POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)	x	
[ ]	[ ]	BOULDER(9)			[x]	[ ]	SAND(6)	x	
[ ]	[ ]	COBBLE(8)	x		[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[x]	DETRITUS(3)	x	
[ ]	[ ]	MUCK/SILT(2)	x		[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [x] >4(2) [ ] <4(0)

SUBSTRATE ORIGIN (all)
- [ ] LIMESTONE(1)
- [x] TILLS(1)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)
- [ ] RIP/RAP(0)
- [ ] HARDPAN(0)

SILT COVER (one)
- [x] SILT-HEAVY(-2)
- [ ] SILT-MOD(-1)
- [ ] SILT-NORM(0)
- [ ] SILT-FREE(1)

Extent of Embeddedness (check one)
- [x] EXTENSIVE(-2)
- [x] MODERATE(-1)
- [ ] LOW(0)
- [ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER:

COVER SCORE 6

TYPE (Check all that apply)
- [ ] UNDERCUT BANKS(1)
- [ ] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [x] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [x] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)
- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [x] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 12

SINUOSITY
- [ ] HIGH(4)
- [x] MODERATE(3)
- [ ] LOW(2)
- [ ] NONE(1)

DEVELOPMENT
- [ ] EXCELLENT(7)
- [ ] GOOD(5)
- [x] FAIR(3)
- [ ] POOR(1)

CHANNELIZATION
- [ ] NONE(6)
- [x] RECOVERED(4)
- [ ] RECOVERING(3)
- [ ] RECENT OR NO RECOVERY(1)

STABILITY
- [ ] HIGH(3)
- [x] MODERATE(2)
- [ ] LOW(1)

MODIFICATION/OTHER
- [x] SNAGGING
- [ ] RELOCATION
- [ ] CANOPY REMOVAL
- [ ] DREDGING
- [ ] ONE SIDE CHANNEL MODIFICATION
- [ ] IMPOUND
- [ ] ISLAND
- [ ] LEVEED
- [ ] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 5

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[x]	[x]	MODERATE 30-150 ft.(3)
[ ]	[ ]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[x]	[x]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[ ]	[ ]	NONE OR LITTLE(3)
[x]	[x]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 0

MAX.DEPTH (Check 1)
- [ ] >4 ft.(6)
- [ ] 2.4-4 ft.(4)
- [ ] 1.2-2.4 ft.(2)
- [ ] <1.2 ft.(1)
- [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)
- [ ] POOL WIDTH>RIFFLE WIDTH(2)
- [ ] POOL WIDTH=RIFFLE WIDTH(1)
- [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
- [ ] TORRENTIAL(-1)
- [ ] FAST(1)
- [ ] MODERATE(1)
- [ ] SLOW(1)
- [ ] EDDIES(1)
- [ ] INTERSTITIAL(-1)
- [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 0

RIFFLE/RUN DEPTH
- [ ] GENERALLY >4 in. MAX.>20 in.(4)
- [ ] GENERALLY >4 in. MAX.<20 in.(3)
- [ ] GENERALLY 2-4 in.(1)
- [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE
- [ ] STABLE (e.g., Cobble,Boulder)(2)
- [ ] MOD.STABLE (e.g., Pea Gravel)(1)
- [ ] UNSTABLE (Gravel, Sand)(0)
- [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS
- [ ] EXTENSIVE(-1)
- [ ] MODERATE(0)
- [ ] LOW(1)
- [ ] NONE(2)
- [ ] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 4.8

% POOL 0 % RIFFLE 0 % RUN 100 **GRADIENT SCORE** 6

STREAM: Site 3: Curtis Creek **RIVER MILE:** ______ **DATE:** 6/24/2002 **QHEI SCORE** 43

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 6

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[x]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[ ]	[ ]	SAND(6)	x	
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[ ]	DETRITUS(3)		x
[ ]	[x]	MUCK/SILT(2)			[ ]	[ ]	ARTIFIC(0)		

SUBSTRATE ORIGIN (all)

- [ ] LIMESTONE(1)
- [ ] RIP/RAP(0)
- [x] TILLS(1)
- [ ] HARDPAN(0)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)

SILT COVER (one)

- [x] SILT-HEAVY(-2)
- [ ] SILT-MOD(-1)
- [ ] SILT-NORM(0)
- [ ] SILT-FREE(1)

Extent of Embeddedness (check one)

- [x] EXTENSIVE(-2)
- [ ] MODERATE(-1)
- [ ] LOW(0)
- [ ] NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER: **COVER SCORE** 7

TYPE (Check all that apply)

- [x] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [x] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [ ] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [x] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** 7

SINUOSITY

- [ ] HIGH(4)
- [ ] MODERATE(3)
- [x] LOW(2)
- [ ] NONE(1)

DEVELOPMENT

- [ ] EXCELLENT(7)
- [ ] GOOD(5)
- [x] FAIR(3)
- [ ] POOR(1)

CHANNELIZATION

- [ ] NONE(6)
- [ ] RECOVERED(4)
- [ ] RECOVERING(3)
- [x] RECENT OR NO RECOVERY(1)

STABILITY

- [ ] HIGH(3)
- [ ] MODERATE(2)
- [x] LOW(1)

MODIFICATION/OTHER

- [x] SNAGGING
- [ ] IMPOUND
- [ ] RELOCATION
- [ ] ISLAND
- [ ] CANOPY REMOVAL
- [ ] LEVEED
- [ ] DREDGING
- [ ] BANK SHAPING
- [ ] ONE SIDE CHANNEL MODIFICATION

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 4

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[x]	[x]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[x]	[ ]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[x]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[ ]	[ ]	NONE OR LITTLE(3)
[ ]	[x]	MODERATE(2)
[x]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 10

MAX.DEPTH (Check 1)

- [x] >4 ft.(6)
- [ ] 2.4-4 ft.(4)
- [ ] 1.2-2.4 ft.(2)
- [ ] <1.2 ft.(1)
- [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)

- [x] POOL WIDTH>RIFFLE WIDTH(2)
- [ ] POOL WIDTH=RIFFLE WIDTH(1)
- [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)

- [ ] TORRENTIAL(-1)
- [x] EDDIES(1)
- [ ] FAST(1)
- [ ] INTERSTITIAL(-1)
- [ ] MODERATE(1)
- [ ] INTERMITTENT(-2)
- [x] SLOW(1)

COMMENTS:

RIFFLE SCORE 3

RIFFLE/RUN DEPTH

- [x] GENERALLY >4 in. MAX.>20 in.(4)
- [ ] GENERALLY >4 in. MAX.<20 in.(3)
- [ ] GENERALLY 2-4 in.(1)
- [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE

- [ ] STABLE (e.g., Cobble,Boulder)(2)
- [ ] MOD.STABLE (e.g., Pea Gravel)(1)
- [ ] UNSTABLE (Gravel, Sand)(0)
- [x] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS

- [x] EXTENSIVE(-1)
- [ ] NONE(2)
- [ ] MODERATE(0)
- [ ] NO RIFFLE(0)
- [ ] LOW(1)

COMMENTS:

6) GRADIENT (FEET/MILE): 4.48 **% POOL** 15 **% RIFFLE** 5 **% RUN** 80 **GRADIENT SCORE** 6

STREAM: Site 4: Curtis Creek **RIVER MILE:** ______ **DATE:** 6/24/2002 **QHEI SCORE** 38

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 2

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)	x	x
[ ]	[ ]	BOULDER(9)			[ ]	[ ]	SAND(6)	x	x
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[x]	DETRITUS(3)		
[ ]	[x]	MUCK/SILT(2)			[ ]	[ ]	ARTIFIC(0)		

SUBSTRATE ORIGIN (all)
- [ ] LIMESTONE(1)
- [ ] RIP/RAP(0)
- [x] TILLS(1)
- [ ] HARDPAN(0)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)

SILT COVER (one)
- [x] SILT-HEAVY(-2)
- [ ] SILT-MOD(-1)
- [ ] SILT-NORM(0)
- [ ] SILT-FREE(1)

Extent of Embeddedness (check one)
- [x] EXTENSIVE(-2)
- [ ] MODERATE(-1)
- [ ] LOW(0)
- [ ] NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: ______

2) INSTREAM COVER: **COVER SCORE** 9

TYPE (Check all that apply)
- [ ] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [x] DEEP POOLS(2)
- [x] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [x] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)
- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [x] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS: ______

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** 5

SINUOSITY
- [ ] HIGH(4)
- [ ] MODERATE(3)
- [ ] LOW(2)
- [x] NONE(1)

DEVELOPMENT
- [ ] EXCELLENT(7)
- [ ] GOOD(5)
- [ ] FAIR(3)
- [x] POOR(1)

CHANNELIZATION
- [ ] NONE(6)
- [ ] RECOVERED(4)
- [ ] RECOVERING(3)
- [x] RECENT OR NO RECOVERY(1)

STABILITY
- [ ] HIGH(3)
- [x] MODERATE(2)
- [ ] LOW(1)

MODIFICATION/OTHER
- [x] SNAGGING
- [ ] IMPOUND
- [ ] RELOCATION
- [x] ISLAND
- [ ] CANOPY REMOVAL
- [ ] LEVEED
- [ ] DREDGING
- [ ] BANK SHAPING
- [ ] ONE SIDE CHANNEL MODIFICATION

COMMENTS: ______

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 4.5

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[x]	[x]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	[x]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[x]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[ ]	[ ]	NONE OR LITTLE(3)
[x]	[x]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS: ______

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 7

MAX.DEPTH (Check 1)
- [ ] >4 ft.(6)
- [x] 2.4-4 ft.(4)
- [ ] 1.2-2.4 ft.(2)
- [ ] <1.2 ft.(1)
- [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)
- [ ] POOL WIDTH>RIFFLE WIDTH(2)
- [x] POOL WIDTH=RIFFLE WIDTH(1)
- [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
- [ ] TORRENTIAL(-1)
- [ ] FAST(1)
- [ ] MODERATE(1)
- [x] SLOW(1)
- [x] EDDIES(1)
- [ ] INTERSTITIAL(-1)
- [ ] INTERMITTENT(-2)

COMMENTS: ______

RIFFLE SCORE 2

RIFFLE/RUN DEPTH
- [ ] GENERALLY >4 in. MAX.>20 in.(4)
- [x] GENERALLY >4 in. MAX.<20 in.(3)
- [ ] GENERALLY 2-4 in.(1)
- [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE
- [ ] STABLE (e.g., Cobble,Boulder)(2)
- [ ] MOD.STABLE (e.g., Pea Gravel)(1)
- [x] UNSTABLE (Gravel, Sand)(0)
- [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS
- [x] EXTENSIVE(-1)
- [ ] NONE(2)
- [ ] MODERATE(0)
- [ ] NO RIFFLE(0)
- [ ] LOW(1)

COMMENTS: ______

6) GRADIENT (FEET/MILE): 6.72 **% POOL** 10 **% RIFFLE** 10 **% RUN** 80 **GRADIENT SCORE** 8

STREAM: Site 5: Long Ditch **RIVER MILE:** ______ **DATE:** 6/25/2002 **QHEI SCORE** 42

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 10

TYPE			POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)		
[ ]	[ ]	BOULDER(9)	x	
[ ]	[ ]	COBBLE(8)		
[ ]	[ ]	HARDPAN(4)		
[ ]	[ ]	MUCK/SILT(2)		
[ ]	[ ]	GRAVEL(7)	x	
[ ]	[x]	SAND(6)		
[ ]	[ ]	BEDROCK(5)		
[x]	[ ]	DETRITUS(3)		
[ ]	[ ]	ARTIFIC(0)		

SUBSTRATE ORIGIN (all)
- [ ] LIMESTONE(1)
- [x] TILLS(1)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)
- [ ] RIP/RAP(0)
- [ ] HARDPAN(0)

SILT COVER (one)
- [ ] SILT-HEAVY(-2)
- [x] SILT-MOD(-1)
- [ ] SILT-NORM(0)
- [ ] SILT-FREE(1)

Extent of Embeddedness (check one)
- [ ] EXTENSIVE(-2)
- [x] MODERATE(-1)
- [ ] LOW(0)
- [ ] NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER:

COVER SCORE 7

TYPE (Check all that apply)
- [ ] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [x] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [x] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)
- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [x] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 10

SINUOSITY
- [ ] HIGH(4)
- [ ] MODERATE(3)
- [x] LOW(2)
- [ ] NONE(1)

DEVELOPMENT
- [ ] EXCELLENT(7)
- [ ] GOOD(5)
- [x] FAIR(3)
- [ ] POOR(1)

CHANNELIZATION
- [ ] NONE(6)
- [ ] RECOVERED(4)
- [x] RECOVERING(3)
- [ ] RECENT OR NO RECOVERY(1)

STABILITY
- [ ] HIGH(3)
- [x] MODERATE(2)
- [ ] LOW(1)

MODIFICATION/OTHER
- [x] SNAGGING
- [ ] RELOCATION
- [ ] CANOPY REMOVAL
- [ ] DREDGING
- [ ] ONE SIDE CHANNEL MODIFICATION
- [ ] IMPOUND
- [ ] ISLAND
- [ ] LEVEED
- [ ] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 7

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[x]	WIDE >150 ft.(4)
[x]	[ ]	MODERATE 30-150 ft.(3)
[ ]	[ ]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[x]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[x]	[ ]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[x]	[x]	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 5

MAX.DEPTH (Check 1)
- [ ] >4 ft.(6)
- [ ] 2.4-4 ft.(4)
- [ ] 1.2-2.4 ft.(2)
- [x] <1.2 ft.(1)
- [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)
- [x] POOL WIDTH>RIFFLE WIDTH(2)
- [ ] POOL WIDTH=RIFFLE WIDTH(1)
- [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
- [ ] TORRENTIAL(-1)
- [ ] FAST(1)
- [ ] MODERATE(1)
- [x] SLOW(1)
- [x] EDDIES(1)
- [ ] INTERSTITIAL(-1)
- [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 3

RIFFLE/RUN DEPTH
- [ ] GENERALLY >4 in. MAX.>20 in.(4)
- [x] GENERALLY >4 in. MAX.<20 in.(3)
- [ ] GENERALLY 2-4 in.(1)
- [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE
- [ ] STABLE (e.g., Cobble,Boulder)(2)
- [ ] MOD.STABLE (e.g., Pea Gravel)(1)
- [x] UNSTABLE (Gravel, Sand)(0)
- [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS
- [ ] EXTENSIVE(-1)
- [x] MODERATE(0)
- [ ] LOW(1)
- [ ] NONE(2)
- [ ] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 0.104

% POOL 10 **% RIFFLE** 5 **% RUN** 85 **GRADIENT SCORE** 2

STREAM: Site 6: Curtis Creek **RIVER MILE:** ______ **DATE:** 6/25/2002 **QHEI SCORE** 27

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 8

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)	x	
[ ]	[ ]	BOULDER(9)			x	[ ]	SAND(6)		
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	x	DETRITUS(3)		
[ ]	[ ]	MUCK/SILT(2)	x		[ ]	[ ]	ARTIFIC(0)		

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [x] TILLS(1) [ ] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [ ] SILT-HEAVY(-2) [ ] SILT-MOD(-1) [x] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [x] EXTENSIVE(-2) [ ] MODERATE(-1) [ ] LOW(0) [ ] NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER: **COVER SCORE** 4

TYPE (Check all that apply)

[ ] UNDERCUT BANKS(1) [ ] OVERHANGING VEGETATION(1) [ ] SHALLOWS (IN SLOW WATER)(1) [ ] DEEP POOLS(2) [ ] ROOTWADS(1) [ ] BOULDERS(1) [ ] OXBOWS(1) [X] AQUATIC MACROPHYTES(1) [ ] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

[ ] EXTENSIVE >75%(11) [ ] MODERATE 25-75%(7) [X] SPARSE 5-25%(3) [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** 5

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [ ] LOW(2) [x] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [ ] FAIR(3) [X] POOR(1)

CHANNELIZATION: [ ] NONE(6) [ ] RECOVERED(4) [X] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [X] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [ ] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [ ] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 4

River Right Looking Downstream

RIPARIAN WIDTH (per bank), L R: [ ][ ] WIDE >150 ft.(4) [ ][ ] MODERATE 30-150 ft.(3) [ ][ ] NARROW 15-30 ft.(2) [x][X] VERY NARROW 3-15 ft.(1) [ ][ ] NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY, L R (most predominant per bank): [ ][ ] FOREST, SWAMP(3) [X][X] OPEN PASTURE/ROW CROP(0) [ ][ ] RESID.,PARK,NEW FIELD(1) [ ][ ] FENCED PASTURE(1)

L R (per bank): [ ][ ] URBAN OR INDUSTRIAL(0) [ ][ ] SHRUB OR OLD FIELD(2) [ ][ ] CONSERV. TILLAGE(1) [ ][ ] MINING/CONSTRUCTION(0)

BANK EROSION, L R (per bank): [X][X] NONE OR LITTLE(3) [ ][ ] MODERATE(2) [ ][ ] HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 0

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [ ] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [ ] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [ ] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [ ] MODERATE(1) [ ] SLOW(1) [ ] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 0

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [ ] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [ ] UNSTABLE (Gravel, Sand)(0) [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [ ] MODERATE(0) [ ] LOW(1) [ ] NONE(2) [ ] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 5.6 **% POOL** 0 **% RIFFLE** 0 **% RUN** 100 **GRADIENT SCORE** 6

STREAM: Site 7: Elijah Ditch **RIVER MILE:** ______ **DATE:** 6/25/2002 **QHEI SCORE** 36

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 9

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[x]	[ ]	SAND(6)		
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[x]	DETRITUS(3)		
[ ]	[ ]	MUCK/SILT(2)	x		[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [ ] RIP/RAP(0) [x] TILLS(1) [ ] HARDPAN(0) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2)

SILT COVER (one): [ ] SILT-HEAVY(-2) [ ] SILT-MOD(-1) [x] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [ ] EXTENSIVE(-2) [x] MODERATE(-1) [ ] LOW(0) [ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: ______

2) INSTREAM COVER: **COVER SCORE** 10

TYPE (Check all that apply)

- [ ] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [ ] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [ ] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [x] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [x] MODERATE 25-75%(7)
- [ ] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS: ______

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** 8

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [x] LOW(2) [ ] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [ ] GOOD(5) [ ] FAIR(3) [x] POOR(1)

CHANNELIZATION: [ ] NONE(6) [ ] RECOVERED(4) [x] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [x] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [x] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [ ] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [ ] BANK SHAPING

COMMENTS: ______

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 5

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[x]	[x]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[x]	[x]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[x]	[x]	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS: ______

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 0

MAX.DEPTH (Check 1): [ ] >4 ft.(6) [ ] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [ ] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [ ] POOL WIDTH>RIFFLE WIDTH(2) [ ] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [ ] MODERATE(1) [ ] SLOW(1) [ ] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS: ______

RIFFLE SCORE 0

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [ ] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [x] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [ ] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [ ] UNSTABLE (Gravel, Sand)(0) [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [ ] MODERATE(0) [ ] LOW(1) [ ] NONE(2) [ ] NO RIFFLE(0)

COMMENTS: ______

6) GRADIENT (FEET/MILE): 2.688 **% POOL** 0 **% RIFFLE** 0 **% RUN** 100 **GRADIENT SCORE** 4

STREAM: Site 8: Kosta Ditch **RIVER MILE:** ______ **DATE:** 6/25/2002 **QHEI SCORE** 36

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** 8

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[x]	[ ]	SAND(6)	x	x
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[ ]	[x]	DETRITUS(3)		
[ ]	[ ]	MUCK/SILT(2)	x	x	[ ]	[ ]	ARTIFIC(0)		

SUBSTRATE ORIGIN (all)
- [ ] LIMESTONE(1)
- [x] TILLS(1)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)
- [ ] RIP/RAP(0)
- [ ] HARDPAN(0)

SILT COVER (one)
- [ ] SILT-HEAVY(-2)
- [ ] SILT-MOD(-1)
- [x] SILT-NORM(0)
- [ ] SILT-FREE(1)

Extent of Embeddedness (check one)
- [x] EXTENSIVE(-2)
- [ ] MODERATE(-1)
- [ ] LOW(0)
- [ ] NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER: **COVER SCORE** 6

TYPE (Check all that apply)
- [ ] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [x] SHALLOWS (IN SLOW WATER)(1)
- [ ] DEEP POOLS(2)
- [ ] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [x] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)
- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [x] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** 7

SINUOSITY
- [ ] HIGH(4)
- [ ] MODERATE(3)
- [x] LOW(2)
- [ ] NONE(1)

DEVELOPMENT
- [ ] EXCELLENT(7)
- [ ] GOOD(5)
- [ ] FAIR(3)
- [x] POOR(1)

CHANNELIZATION
- [ ] NONE(6)
- [ ] RECOVERED(4)
- [x] RECOVERING(3)
- [ ] RECENT OR NO RECOVERY(1)

STABILITY
- [ ] HIGH(3)
- [ ] MODERATE(2)
- [x] LOW(1)

MODIFICATION/OTHER
- [ ] SNAGGING
- [ ] RELOCATION
- [ ] CANOPY REMOVAL
- [ ] DREDGING
- [ ] ONE SIDE CHANNEL MODIFICATION
- [ ] IMPOUND
- [ ] ISLAND
- [ ] LEVEED
- [ ] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** 4

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[ ]	[ ]	NARROW 15-30 ft.(2)
[x]	[x]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[x]	[x]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[x]	[x]	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** 4

MAX.DEPTH (Check 1)
- [ ] >4 ft.(6)
- [ ] 2.4-4 ft.(4)
- [x] 1.2-2.4 ft.(2)
- [ ] <1.2 ft.(1)
- [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)
- [ ] POOL WIDTH>RIFFLE WIDTH(2)
- [ ] POOL WIDTH=RIFFLE WIDTH(1)
- [x] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
- [ ] TORRENTIAL(-1)
- [ ] FAST(1)
- [x] MODERATE(1)
- [ ] SLOW(1)
- [x] EDDIES(1)
- [ ] INTERSTITIAL(-1)
- [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 2

RIFFLE/RUN DEPTH
- [ ] GENERALLY >4 in. MAX.>20 in.(4)
- [x] GENERALLY >4 in. MAX.<20 in.(3)
- [ ] GENERALLY 2-4 in.(1)
- [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE
- [ ] STABLE (e.g., Cobble,Boulder)(2)
- [ ] MOD.STABLE (e.g., Pea Gravel)(1)
- [x] UNSTABLE (Gravel, Sand)(0)
- [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS
- [x] EXTENSIVE(-1)
- [ ] MODERATE(0)
- [ ] LOW(1)
- [ ] NONE(2)
- [ ] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 2.688 **% POOL** 5 **% RIFFLE** 5 **% RUN** 90 **GRADIENT SCORE** 4

STREAM: Site 9: Curtis Creek **RIVER MILE:** ______ **DATE:** 6/25/2002 **QHEI SCORE** 36

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 8

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[ ]	[x]	SAND(6)		
[ ]	[ ]	COBBLE(8)	x		[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[x]	[ ]	DETRITUS(3)		
[ ]	[ ]	MUCK/SILT(2)			[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

SUBSTRATE ORIGIN (all)		SILT COVER (one)	
[ ] LIMESTONE(1)	[x] RIP/RAP(0)	[ ] SILT-HEAVY(-2)	[ ] SILT-MOD(-1)
[x] TILLS(1)	[ ] HARDPAN(0)	[x] SILT-NORM(0)	[ ] SILT-FREE(1)
[ ] SANDSTONE(0)		**Extent of Embeddedness (check one)**	
[ ] SHALE(-1)		[ ] EXTENSIVE(-2)	[ ] MODERATE(-1)
[ ] COAL FINES(-2)		[x] LOW(0)	[ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER:

COVER SCORE 7

TYPE (Check all that apply)

[ ] UNDERCUT BANKS(1)	[ ] DEEP POOLS(2)	[ ] OXBOWS(1)
[x] OVERHANGING VEGETATION(1)	[x] ROOTWADS(1)	[x] AQUATIC MACROPHYTES(1)
[ ] SHALLOWS (IN SLOW WATER)(1)	[ ] BOULDERS(1)	[x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [x] MODERATE 25-75%(7)
- [ ] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 6.5

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER	
[ ] HIGH(4)	[ ] EXCELLENT(7)	[ ] NONE(6)	[ ] HIGH(3)	[ ] SNAGGING	[ ] IMPOUND
[ ] MODERATE(3)	[ ] GOOD(5)	[x] RECOVERED(4)	[x] MODERATE(2)	[ ] RELOCATION	[ ] ISLAND
[x] LOW(2)	[ ] FAIR(3)	[ ] RECOVERING(3)	[ ] LOW(1)	[ ] CANOPY REMOVAL	[ ] LEVEED
[x] NONE(1)	[x] POOR(1)	[ ] RECENT OR NO RECOVERY(1)		[ ] DREDGING	[ ] BANK SHAPING
				[ ] ONE SIDE CHANNEL MODIFICATION	

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 4

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[ ]	[ ]	NARROW 15-30 ft.(2)
[x]	[x]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[x]	[x]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[x]	[x]	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 6

MAX.DEPTH (Check 1)	MORPHOLOGY (Check 1)	POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)	
[ ] >4 ft.(6)	[x] POOL WIDTH>RIFFLE WIDTH(2)	[ ] TORRENTIAL(-1)	[x] EDDIES(1)
[ ] 2.4-4 ft.(4)	[ ] POOL WIDTH=RIFFLE WIDTH(1)	[ ] FAST(1)	[ ] INTERSTITIAL(-1)
[x] 1.2-2.4 ft.(2)	[ ] POOL WIDTH<RIFFLE WIDTH(0)	[ ] MODERATE(1)	[ ] INTERMITTENT(-2)
[ ] <1.2 ft.(1)		[x] SLOW(1)	
[ ] <0.6 ft.(Pool=0)(0)			

COMMENTS:

RIFFLE SCORE 4

RIFFLE/RUN DEPTH	RIFFLE/RUN SUBSTRATE	RIFFLE/RUN EMBEDDEDNESS	
[ ] GENERALLY >4 in. MAX.>20 in.(4)	[ ] STABLE (e.g., Cobble,Boulder)(2)	[ ] EXTENSIVE(-1)	[ ] NONE(2)
[x] GENERALLY >4 in. MAX.<20 in.(3)	[x] MOD.STABLE (e.g., Pea Gravel)(1)	[x] MODERATE(0)	[ ] NO RIFFLE(0)
[ ] GENERALLY 2-4 in.(1)	[ ] UNSTABLE (Gravel, Sand)(0)	[ ] LOW(1)	
[ ] GENERALLY <2 in.(Riffle=0)(0)	[ ] NO RIFFLE(0)		

COMMENTS:

6) GRADIENT (FEET/MILE): 4.48

% POOL 5 **% RIFFLE** 5 **% RUN** 90 **GRADIENT SCORE** 6

STREAM: Site 10: Unnamed Tributary **RIVER MILE:** ____ **DATE:** 6/25/2002 **QHEI SCORE** 23

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 8

TYPE			POOL	RIFFLE				POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)			[ ]	[ ]	GRAVEL(7)		
[ ]	[ ]	BOULDER(9)			[ ]	[x]	SAND(6)		
[ ]	[ ]	COBBLE(8)			[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	HARDPAN(4)			[x]	[ ]	DETRITUS(3)		
[ ]	[ ]	MUCK/SILT(2)			[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [ ] >4(2) [x] <4(0)

SUBSTRATE ORIGIN (all)
- [ ] LIMESTONE(1) [ ] RIP/RAP(0)
- [x] TILLS(1) [ ] HARDPAN(0)
- [ ] SANDSTONE(0)
- [ ] SHALE(-1)
- [ ] COAL FINES(-2)

SILT COVER (one)
- [ ] SILT-HEAVY(-2) [x] SILT-MOD(-1)
- [ ] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one)
- [ ] EXTENSIVE(-2) [x] MODERATE(-1)
- [ ] LOW(0) [ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER:

COVER SCORE 3

TYPE (Check all that apply)
- [ ] UNDERCUT BANKS(1) [ ] DEEP POOLS(2) [ ] OXBOWS(1)
- [x] OVERHANGING VEGETATION(1) [ ] ROOTWADS(1) [x] AQUATIC MACROPHYTES(1)
- [ ] SHALLOWS (IN SLOW WATER)(1) [ ] BOULDERS(1) [ ] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)
- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [ ] SPARSE 5-25%(3)
- [x] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 4

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER	
[ ] HIGH(4)	[ ] EXCELLENT(7)	[ ] NONE(6)	[ ] HIGH(3)	[ ] SNAGGING	[ ] IMPOUND
[ ] MODERATE(3)	[ ] GOOD(5)	[ ] RECOVERED(4)	[x] MODERATE(2)	[ ] RELOCATION	[ ] ISLAND
[ ] LOW(2)	[ ] FAIR(3)	[ ] RECOVERING(3)	[x] LOW(1)	[ ] CANOPY REMOVAL	[ ] LEVEED
[x] NONE(1)	[x] POOR(1)	[x] RECENT OR NO RECOVERY(1)		[ ] DREDGING	[ ] BANK SHAPING
				[ ] ONE SIDE CHANNEL MODIFICATION	

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 3.5

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[ ]	[ ]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[ ]	[x]	NARROW 15-30 ft.(2)
[x]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[ ]	[ ]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[x]	[x]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[ ]	[ ]	NONE OR LITTLE(3)
[x]	[x]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 0

MAX.DEPTH (Check 1)
- [ ] >4 ft.(6)
- [ ] 2.4-4 ft.(4)
- [ ] 1.2-2.4 ft.(2)
- [ ] <1.2 ft.(1)
- [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)
- [ ] POOL WIDTH>RIFFLE WIDTH(2)
- [ ] POOL WIDTH=RIFFLE WIDTH(1)
- [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
- [ ] TORRENTIAL(-1) [ ] EDDIES(1)
- [ ] FAST(1) [ ] INTERSTITIAL(-1)
- [ ] MODERATE(1) [ ] INTERMITTENT(-2)
- [ ] SLOW(1)

COMMENTS:

RIFFLE SCORE 0

RIFFLE/RUN DEPTH
- [ ] GENERALLY >4 in. MAX.>20 in.(4)
- [ ] GENERALLY >4 in. MAX.<20 in.(3)
- [ ] GENERALLY 2-4 in.(1)
- [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE
- [ ] STABLE (e.g., Cobble,Boulder)(2)
- [ ] MOD.STABLE (e.g., Pea Gravel)(1)
- [ ] UNSTABLE (Gravel, Sand)(0)
- [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS
- [ ] EXTENSIVE(-1) [ ] NONE(2)
- [ ] MODERATE(0) [ ] NO RIFFLE(0)
- [ ] LOW(1)

COMMENTS:

6) GRADIENT (FEET/MILE): 2.48

% POOL 0 % RIFFLE 0 % RUN 100 **GRADIENT SCORE** 4

STREAM: Reference Site: Beaver Creek **RIVER MILE:** ______ **DATE:** 7/23/2002 **QHEI SCORE** 68

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present)

SUBSTRATE SCORE 17

TYPE			POOL	RIFFLE
[ ]	[ ]	BLDER/SLAB(10)		
[ ]	[ ]	BOULDER(9)		
[ ]	[x]	COBBLE(8)	x	x
[ ]	[ ]	HARDPAN(4)		
[ ]	[ ]	MUCK/SILT(2)		
[ ]	[x]	GRAVEL(7)	x	x
[ ]	[ ]	SAND(6)	x	x
[ ]	[ ]	BEDROCK(5)		
[ ]	[ ]	DETRITUS(3)		
[ ]	[ ]	ARTIFIC(0)		

TOTAL NUMBER OF SUBSTRATE TYPES: [x] >4(2) [ ] <4(0)

SUBSTRATE ORIGIN (all): [ ] LIMESTONE(1) [x] TILLS(1) [ ] SANDSTONE(0) [ ] SHALE(-1) [ ] COAL FINES(-2) [ ] RIP/RAP(0) [ ] HARDPAN(0)

SILT COVER (one): [ ] SILT-HEAVY(-2) [ ] SILT-MOD(-1) [x] SILT-NORM(0) [ ] SILT-FREE(1)

Extent of Embeddedness (check one): [ ] EXTENSIVE(-2) [ ] MODERATE(-1) [ ] LOW(0) [ ] NONE(1)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS:

2) INSTREAM COVER:

COVER SCORE 8

TYPE (Check all that apply)

- [x] UNDERCUT BANKS(1)
- [x] OVERHANGING VEGETATION(1)
- [x] SHALLOWS (IN SLOW WATER)(1)
- [x] DEEP POOLS(2)
- [x] ROOTWADS(1)
- [ ] BOULDERS(1)
- [ ] OXBOWS(1)
- [ ] AQUATIC MACROPHYTES(1)
- [x] LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)

- [ ] EXTENSIVE >75%(11)
- [ ] MODERATE 25-75%(7)
- [x] SPARSE 5-25%(3)
- [ ] NEARLY ABSENT <5%(1)

COMMENTS:

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE)

CHANNEL SCORE 14

SINUOSITY: [ ] HIGH(4) [ ] MODERATE(3) [x] LOW(2) [ ] NONE(1)

DEVELOPMENT: [ ] EXCELLENT(7) [x] GOOD(5) [x] FAIR(3) [ ] POOR(1)

CHANNELIZATION: [x] NONE(6) [ ] RECOVERED(4) [ ] RECOVERING(3) [ ] RECENT OR NO RECOVERY(1)

STABILITY: [ ] HIGH(3) [x] MODERATE(2) [ ] LOW(1)

MODIFICATION/OTHER: [ ] SNAGGING [ ] RELOCATION [ ] CANOPY REMOVAL [ ] DREDGING [ ] ONE SIDE CHANNEL MODIFICATION [ ] IMPOUND [ ] ISLAND [ ] LEVEED [ ] BANK SHAPING

COMMENTS:

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank)

RIPARIAN SCORE 10

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L	R	(per bank)
[x]	[x]	WIDE >150 ft.(4)
[ ]	[ ]	MODERATE 30-150 ft.(3)
[ ]	[ ]	NARROW 15-30 ft.(2)
[ ]	[ ]	VERY NARROW 3-15 ft.(1)
[ ]	[ ]	NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L	R	(most predominant per bank)	L	R	(per bank)
[x]	[x]	FOREST, SWAMP(3)	[ ]	[ ]	URBAN OR INDUSTRIAL(0)
[ ]	[ ]	OPEN PASTURE/ROW CROP(0)	[ ]	[ ]	SHRUB OR OLD FIELD(2)
[ ]	[ ]	RESID.,PARK,NEW FIELD(1)	[ ]	[ ]	CONSERV. TILLAGE(1)
[ ]	[ ]	FENCED PASTURE(1)	[ ]	[ ]	MINING/CONSTRUCTION(0)

BANK EROSION

L	R	(per bank)
[x]	[x]	NONE OR LITTLE(3)
[ ]	[ ]	MODERATE(2)
[ ]	[ ]	HEAVY OR SEVERE(1)

COMMENTS:

5) POOL/GLIDE AND RIFFLE/RUN QUALITY

NO POOL = 0 **POOL SCORE** 10

MAX.DEPTH (Check 1): [x] >4 ft.(6) [ ] 2.4-4 ft.(4) [ ] 1.2-2.4 ft.(2) [ ] <1.2 ft.(1) [ ] <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1): [x] POOL WIDTH>RIFFLE WIDTH(2) [ ] POOL WIDTH=RIFFLE WIDTH(1) [ ] POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply): [ ] TORRENTIAL(-1) [ ] FAST(1) [x] MODERATE(1) [ ] SLOW(1) [x] EDDIES(1) [ ] INTERSTITIAL(-1) [ ] INTERMITTENT(-2)

COMMENTS:

RIFFLE SCORE 6

RIFFLE/RUN DEPTH: [ ] GENERALLY >4 in. MAX.>20 in.(4) [x] GENERALLY >4 in. MAX.<20 in.(3) [ ] GENERALLY 2-4 in.(1) [ ] GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE: [x] STABLE (e.g., Cobble,Boulder)(2) [ ] MOD.STABLE (e.g., Pea Gravel)(1) [ ] UNSTABLE (Gravel, Sand)(0) [ ] NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS: [ ] EXTENSIVE(-1) [ ] MODERATE(0) [x] LOW(1) [ ] NONE(2) [ ] NO RIFFLE(0)

COMMENTS:

6) GRADIENT (FEET/MILE): 2.13

% POOL 15 % RIFFLE 10 % RUN 75 **GRADIENT SCORE** 4

APPENDIX 8:

Detailed mIBI Results

APPENDIX 8. Detailed mIBI Results

<u>Site 1. Curtis Creek</u>:

TABLE 8.1 Site 1 multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	1		4	4	0.87
Coleoptera	Chrysomeiidae	4			0	3.48
Coleoptera	Dytiscidae	1			0	0.87
Coleoptera	Gyrinidae	5		5	25	4.35
Coleoptera	Haliplidae	1		7	7	0.87
Coleoptera	Psephenidae	8		4	32	6.96
Decopoda	Astacidae	12		8	96	10.43
Diptera	Chironomidae	7		6	42	6.09
Diptera	Empididae	1		6	6	0.87
Diptera	Ephydridae	1		6	6	0.87
Diptera	Simuliidae	2		6	12	1.74
Ephemeroptera	Baetidae	9	9	4	36	7.83
Ephemeroptera	Heptageniidae	1	1	4	4	0.87
Gastropoda	Physidae	6		8	48	5.22
Hempitera	Corixidae	9		10	90	7.83
Hempitera	Veliidae	1			0	0.87
Isopoda	Asillidae	4		8	32	3.48
Megaloptera	Nigronia	2			0	1.74
Odonata	Aeshnidae	1		3	3	0.87
Odonata	Agrionidae	4			0	3.48
Odonata	Coenagrionidae	3		9	27	2.61
Odonata	Gomphidae	1		1	1	0.87
Oligochaeta		2			0	1.74
Platyhelminthes	Planaria	19		1	19	16.52
Trichoptera	Hydropsychidae	4	4	4	16	3.48
Trichoptera	Hydroptilidae	6	6	4	24	5.22
		115	**20**		**4.82**	
					HBI	

TABLE 8.2 Site 1 mIBI metrics, June 25, 2002.

		Metric Score
HBI	4.82	4
No. Taxa (family)	26	8
% Dominant Taxa	16.5	8
EPT Index	4	4
EPT Count	20	2
EPT Count/Total Count	0.17	2
EPT Abun./Chir. Abun.	2.86	4
Chironomid Count	7	6
mIBI Score		**4.75**

Site 2. Yeoman Ditch:

TABLE 8.3 Site 2 multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	1		4	4	1.35
Coleoptera	Dytiscidae	4			0	5.41
Coleoptera	Gyrinidae	1		5	5	1.35
Coleoptera	Haliplidae	2		7	14	2.70
Coleoptera	Psephenidae	1		4	4	1.35
Decopoda	Astacidae	3		8	24	4.05
Diptera	Chironomidae	15		6	90	20.27
Gastropoda	Lymnaeidae	4		6	24	5.41
Gastropoda	Physidae	5		8	40	6.76
Gastropoda	Viviparidae	8			0	10.81
Hempitera	Belostomatidae	1			0	1.35
Hempitera	Corixidae	2		10	20	2.70
Hempitera	Gerridae	3		5	15	4.05
Hempitera	Mesoveliidae	3			0	4.05
Hempitera	Notonectidae	12			0	16.22
Hempitera	Veliidae	1			0	1.35
Odonata	Aeshnidae	3		3	9	4.05
Odonata	Agrionidae	1			0	1.35
Odonata	Coenagrionidae	4		9	36	5.41
		74	**0**		**6.48**	
					HBI	

TABLE 8.4 Site 2 mIBI metrics, June 25, 2002.

		Metric Score
HBI	6.48	0
No. Taxa (family)	19	8
% Dominant Taxa	20.3	8
EPT Index	0	0
EPT Count	0	0
EPT Count/Total Count	0.00	0
EPT Abun./Chir. Abun.	0.00	0
Chironomid Count	15	6
mIBI Score		**2.75**

Site 3. Curtis Creek:

TABLE 8.5 Site 3 multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Bivalvia	Sphaeriidae	1		8	8	0.99
Coleoptera	Dytiscidae	1			0	0.99
Coleoptera	Gyrinidae	4		5	20	3.96
Coleoptera	Noteridae	5			0	4.95
Decopoda	Astacidae	11		8	88	10.89
Diptera	Brachyera pupae	1			0	0.99
Diptera	Chironomidae	2		6	12	1.98
Diptera	Simuliidae	4		6	24	3.96
Ephemeroptera	Baetidae	6	6	4	24	5.94
Ephemeroptera	Caenidae	4	4	7	28	3.96
Hempitera	Gerridae	17		5	85	16.83
Hempitera	Mesoveliidae	2			0	1.98
Hempitera	Notonectidae	13			0	12.87
Hempitera	Veliidae	8			0	7.92
Megaloptera	Nigronia	1			0	0.99
Odonata	Aeshnidae	1		3	3	0.99
Odonata	Agrionidae	5			0	4.95
Odonata	Coenagrionidae	1		9	9	0.99
Odonata	Petaluridae	1			0	0.99
Trichoptera	Beraeidtae	1	1		0	0.99
Trichoptera	Brachycentridae	1	1	1	1	0.99
Trichoptera	Hydropsychidae	10	10	4	40	9.90
Trichoptera	Odontoceridae	1	1	0	0	0.99
		101	**23**		**5.43**	
					HBI	

TABLE 8.6 Site 3 mIBI metrics, June 25, 2002.

		Metric Score
HBI	5.43	2
No. Taxa (family)	23	8
% Dominant Taxa	16.8	8
EPT Index	6	6
EPT Count	23	2
EPT Count/Total Count	0.23	2
EPT Abun./Chir. Abun.	11.50	6
Chironomid Count	2	8
mIBI Score		**5.25**

__Site 4. Curtis Creek__:

TABLE 8.7 Site 4 multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	1		4	4	0.93
Bivalvia	Sphaeriidae	3		8	24	2.80
Coleoptera	Dytiscidae	4			0	3.74
Coleoptera	Gyrinidae	1		5	5	0.93
Coleoptera	Haliplidae	1		7	7	0.93
Decopoda	Astacidae	4		8	32	3.74
Diptera	Chironomidae	7		6	42	6.54
Diptera	Ephydridae	2		6	12	1.87
Diptera	Nematocera pupae	1			0	0.93
Diptera	Simuliidae	1		6	6	0.93
Ephemeroptera	Baetidae	11		4	44	10.28
Ephemeroptera	Siphlonuridae	6	6	7	42	5.61
Gastropoda	Lymnaeidae	2		6	12	1.87
Gastropoda	Physidae	9		8	72	8.41
Gastropoda	Planorbidae	1		7	0	0.93
Hempitera	Belostomatidae	1			0	0.93
Hempitera	Corixidae	2		10	20	1.87
Hempitera	Gerridae	8		5	40	7.48
Hempitera	Herbridae	2			0	1.87
Hempitera	Mesoveliidae	3			0	2.80
Hempitera	Naucoridae	2			0	1.87
Hempitera	Notonectidae	20			0	18.69
Megaloptera	Nigronia	3			0	2.80
Odonata	Agrionidae	9			0	8.41
Odonata	Petaluridae	1			0	0.93
Trichoptera	Hydropsychidae	2	2	4	8	1.87
		107	**8**		**6.07**	
					HBI	

TABLE 8.8 Site 4 mIBI metrics, June 25, 2002.

		Metric Score
HBI	6.07	0
No. Taxa (family)	26	8
% Dominant Taxa	18.7	8
EPT Index	3	2
EPT Count	19	0
EPT Count/Total Count	0.18	2
EPT Abun./Chir. Abun.	9.50	6
Chironomid Count	7	6
mIBI Score		**3.5**

Site 5. Long Ditch:

TABLE 8.9 Site 5 multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	20		4	80	21.05
Coleoptera	Chrysomeiidae	1			0	1.05
Coleoptera	Curculionidae	1			0	1.05
Coleoptera	Dytiscidae	7			0	7.37
Coleoptera	Helodidae	1			0	1.05
Decopoda	Astacidae	2		8	16	2.11
Diptera	Chironomidae	23		6	138	24.21
Diptera	Empididae	3		6	18	3.16
Diptera	Ephydridae	2		6	12	2.11
Diptera	Simuliidae	3		6	18	3.16
Hempitera	Corixidae	1		10	10	1.05
Hempitera	Gerridae	6		5	30	6.32
Hempitera	Notonectidae	12			0	12.63
Hempitera	Veliidae	1			0	1.05
Odonata	Aeshnidae	4		3	12	4.21
Oligochaeta		3			0	3.16
Trichoptera	Hydroptilidae	5	5	4	20	5.26
		95	**5**		**5.13**	
					HBI	

TABLE 8.10 Site 5 mIBI metrics, June 25, 2002.

		Metric Score
HBI	5.13	2
No. Taxa (family)	17	6
% Dominant Taxa	24.2	6
EPT Index	1	0
EPT Count	5	0
EPT Count/Total Count	0.05	0
EPT Abun./Chir. Abun.	0.22	0
Chironomid Count	23	4
mIBI Score		**2.25**

Site 6. Curtis Creek:

TABLE 8.11 Site 6 multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Bivalvia	Sphaeriidae	2		8	16	2.02
Coleoptera	Chrysomeiidae	1			0	1.01
Coleoptera	Dytiscidae	9			0	9.09
Coleoptera	Elmidae	2		4	8	2.02
Coleoptera	Hydrophilidae	1		5	5	1.01
Coleoptera	Noteridae	2			0	2.02
Coleoptera	Psephenidae	1		4	4	1.01
Decopoda	Astacidae	3		8	24	3.03
Diptera	Chironomidae	1		6	6	1.01
Diptera	Ephydridae	2		6	12	2.02
Diptera	Stratiomyidae	2			0	2.02
Diptera	Syrphidae	1		10	10	1.01
Ephemeroptera	Caenidae	1	1	7	7	1.01
Gastropoda	Lymnaeidae	2		6	12	2.02
Gastropoda	Planorbidae	1		7	0	1.01
Gastropoda	Pleuroceridae	8			0	8.08
Hempitera	Belostomatidae	4			0	4.04
Hempitera	Notonectidae	1			0	1.01
Megaloptera	Nigronia	2			0	2.02
Odonata	Aeshnidae	2		3	6	2.02
Odonata	Coenagrionidae	16		9	144	16.16
Oligochaeta		1			0	1.01
Platyhelminthes	Planaria	34		1	34	34.34
		99	**1**		**3.94**	
					HBI	

TABLE 8.12 Site 6 mIBI metrics, June 25, 2002.

		Metric Score
HBI	3.94	6
No. Taxa (family)	22	8
% Dominant Taxa	34.3	6
EPT Index	1	0
EPT Count	1	0
EPT Count/Total Count	0.01	0
EPT Abun./Chir. Abun.	0.50	2
Chironomid Count	2	8
mIBI Score		**3.75**

Site 7. Elijah Ditch:

TABLE 8.13 Site 7 multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Acarina	Hydrachridae	1			0	0.00
Amphipoda	Gammaridae	1		4	4	0.80
Coleoptera	Curculionidae	2			0	1.60
Coleoptera	Cyrinidae	1			0	0.80
Coleoptera	Dytiscidae	3			0	2.40
Coleoptera	Elmidae	1		4	4	0.80
Coleoptera	Hydrophilidae	10		5	50	8.00
Coleoptera	Psephenidae	18		4	72	14.40
Diptera	Chironomidae	29		6	174	23.20
Diptera	Culicidae	1			0	0.80
Diptera	Ephydridae	1		6	6	0.80
Diptera	Nematocera pupae	2			0	1.60
Diptera	Stratiomyidae	1			0	0.80
Gastropoda	Physidae	19		8	152	15.20
Gastropoda	Planorbidae	1		7	0	0.80
Gastropoda	Pleuroceridae	4			0	3.20
Gastropoda	Viviparidae	4			0	3.20
Hempitera	Herbridae	1			0	0.80
Hempitera	Notonectidae	14			0	11.20
Hempitera	Veliidae	1			0	0.80
Odonata	Aeshnidae	2		3	6	1.60
Odonata	Agrionidae	1			0	0.80
Odonata	Coenagrionidae	1		9	9	0.80
Odonata	Lestidae	5		9	45	4.00
Odonata	Libellulidae	1		9	9	0.80
		125	**0**		**5.97**	
					HBI	

TABLE 8.14 Site 7 mIBI metrics, June 25, 2002.

		Metric Score
HBI	5.97	0
No. Taxa (family)	25	8
% Dominant Taxa	23.2	6
EPT Index	0	0
EPT Count	0	0
EPT Count/Total Count	0.00	0
EPT Abun./Chir. Abun.	0.00	0
Chironomid Count	29	4
mIBI Score		**2.25**

<u>Site 8. Kosta Ditch</u>:

TABLE 8.15 Site 8 multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Amphizoidae	3			0	2.16
Coleoptera	Chrysomeiidae	6			0	4.32
Coleoptera	Dytiscidae	2			0	1.44
Coleoptera	Elmidae	9		4	36	6.47
Coleoptera	Helodidae	1			0	0.72
Coleoptera	Hydrophilidae	1		5	5	0.72
Decopoda	Astacidae	1		8	8	0.72
Diptera	Chironomidae	36		6	216	25.90
Diptera	Nematocera pupae	1			0	0.72
Diptera	Simuliidae	10		6	60	7.19
Diptera	Tabanidae	1		6	6	0.72
Ephemeroptera	Caenidae	1	1	7	7	0.72
Gastropoda	Planorbidae	1		7	0	0.72
Hempitera	Belostomatidae	12			0	8.63
Hempitera	Gerridae	1		5	5	0.72
Hempitera	Herbridae	8			0	5.76
Hempitera	Mesoveliidae	3			0	2.16
Hempitera	Notonectidae	7			0	5.04
Hempitera	Veliidae	2			0	1.44
Lepidoptera	Langessa	1			0	0.72
Megaloptera	Sialidae	9		4	36	6.47
Odonata	Aeshnidae	9		3	27	6.47
Odonata	Agrionidae	2			0	1.44
Odonata	Lestidae	1		9	9	0.72
Trichoptera	Hydropsychidae	9	9	4	36	6.47
Trichoptera	Hydroptilidae	2	2	4	8	1.44
		139	**12**		**5.04**	
					HBI	

TABLE 8.16 Site 8 mIBI metrics, June 25, 2002.

		Metric Score
HBI	5.04	4
No. Taxa (family)	26	8
% Dominant Taxa	25.9	6
EPT Index	3	2
EPT Count	12	0
EPT Count/Total Count	0.09	0
EPT Abun./Chir. Abun.	0.33	0
Chironomid Count	36	4
mIBI Score		**3.0**

Site 9. Curtis Creek:

TABLE 8.17 Site 9 multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Bivalvia	Sphaeriidae	30		8	240	29.41
Coleoptera	Hydrophilidae	1		5	5	0.98
Diptera	Brachyera pupae	1			0	0.98
Diptera	Chironomidae	7		6	42	6.86
Diptera	Ephydridae	2		6	12	1.96
Diptera	Stratiomyidae	16			0	15.69
Gastropoda	Physidae	3		8	24	2.94
Gastropoda	Planorbidae	2		7	0	1.96
Hempitera	Mesoveliidae	1			0	0.98
Hempitera	Notonectidae	1			0	0.98
Hempitera	Veliidae	5			0	4.90
Odonata	Aeshnidae	1		3	3	0.98
Odonata	Agrionidae	15			0	14.71
Odonata	Coenagrionidae	4		9	36	3.92
Odonata	Lestidae	6		9	54	5.88
Trichoptera	Hydroptilidae	7	7	4	28	6.86
		102	**7**		**6.94**	
					HBI	

TABLE 8.18 Site 9 mIBI metrics, June 25, 2002.

		Metric Score
HBI	6.94	0
No. Taxa (family)	16	6
% Dominant Taxa	29.4	6
EPT Index	1	0
EPT Count	7	0
EPT Count/Total Count	0.07	0
EPT Abun./Chir. Abun.	1.00	2
Chironomid Count	7	6
mIBI Score		**2.5**

Site 10. Unnamed Tributary:

TABLE 8.19 Site 10 multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Araneae	Pisauridae	1			0	0.92
Coleoptera	Amphizoidae	1			0	0.92
Coleoptera	Haliplidae	2		7	14	1.83
Coleoptera	Hydrophilidae	1		5	5	0.92
Decopoda	Astacidae	1		8	8	0.92
Diptera	Ceratopognidae	1		6	6	0.92
Diptera	Chironomidae	40		6	240	36.70
Diptera	Ephydridae	2		6	12	1.83
Diptera	Nematocera pupae	1			0	0.92
Diptera	Simuliidae	1		6	6	0.92
Diptera	Stratiomyidae	1			0	0.92
Diptera	Syrphidae	1		10	10	0.92
Gastropoda	Lymnaeidae	4		6	24	3.67
Gastropoda	Physidae	31		8	248	28.44
Gastropoda	Planorbidae	4		7	0	3.67
Gastropoda	Viviparidae	4			0	3.67
Hempitera	Hydrometridae	1			0	0.92
Hempitera	Notonectidae	1			0	0.92
Hempitera	Veliidae	1			0	0.92
Odonata	Aeshnidae	1		3	3	0.92
Odonata	Agrionidae	5			0	4.59
Odonata	Coenagrionidae	4		9	36	3.67
		109	**0**		**6.58**	
					HBI	

TABLE 8.20 Site 10 mIBI metrics, June 25, 2002.

		Metric Score
HBI	6.58	0
No. Taxa (family)	22	8
% Dominant Taxa	36.7	4
EPT Index	0	0
EPT Count	0	0
EPT Count/Total Count	0.00	0
EPT Abun./Chir. Abun.	0.00	2
Chironomid Count	40	4
mIBI Score		**2.25**

Reference Site: Beaver Creek:

TABLE 8.21 Reference site multi-habitat macroinvertebrate results, June 25, 2002.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Chrysomelidae	7			0	7.37
Coleoptera	Dytiscidae	1			0	1.05
Coleoptera	Elmidae	2		4	8	2.11
Coleoptera	Gyrinidae	1		5	5	1.05
Coleoptera	Hydrophilidae	1		5	5	1.05
Decapoda	Astacidae	1		8	8	1.05
Diptera	Chironiomidae	7		6	42	7.37
Empemeroptera	Baetidae	2	2	4	8	2.11
Empemeroptera	Ephemerellidae	2	2	1	2	2.11
Empemeroptera	Heptageniidae	9	9	4	36	9.47
Empemeroptera	Neoephemeridae	2	2		0	2.11
Empemeroptera	Tricorythidae	2	2	4	8	2.11
Hemiptera	Belostomatidae	1			0	1.05
Hemiptera	Gerridae	1		5	5	1.05
Hemiptera	Notonectidae	3			0	3.16
Odonata	Agrionidae	2			0	2.11
Odonata	Coenagrionidae	2		9	18	2.11
Trichoptera	Hydropsychidae	49	49	4	196	51.58
		95	**66**		**4.32**	
					HBI	

TABLE 8.22 Reference site mIBI metrics, June 25, 2002.

		Metric Score
HBI	4.32	6
No. Taxa (family)	18	8
% Dominant Taxa	51.6	2
EPT Index	6	6
EPT Count	66	4
EPT Count/Total Count	0.69	8
EPT Abun./Chir. Abun.	9.43	6
Chironomid Count	7	6
mIBI Score		**5.75**

Things you can do to help:

- ★ If you live in the Curtis Creek Watershed, consider contacting the Newton or Jasper County SWCD to inquire about cost-share money available for water quality improvement projects on your property.
- ★ Avoid fertilizing near the stream's edge.
- ★ Examine all drains that lead from roads and fields to the stream and consider alternate routes for these drains that would filter pollutants before they reach the water.
- ★ Keep organic debris and animal waste out of the water.
- ★ Fence cattle and livestock away from the stream's edge.
- ★ Avoid mowing up to the stream's edge to allow for natural stream-side grass and shrub growth which will help stabilize banks.
- ★ Properly maintain existing septic systems by pumping regularly and caring for leach fields. Undue pressure on systems may be alleviated by water conservation practices.
- ★ Maintain field drainage tiles and use buffer strips around tile risers.
- ★ Consider working with the Newton and Jasper County Soil and Water Conservation Districts to formulate a Resource Management Plan for your property.

For additional information on how to keep your watershed clean and healthy contact:

Lake and River Enhancement Program
Indiana Department of Natural Resources
(IDNR) Division of Soil Conservation
402 W. Washington Street Room 265
Indianapolis, Indiana 46204
(317) 233-3870

Newton County SWCD
213 East North Street
Morocco, Indiana 47963
(219) 285-6889

Jasper County SWCD
800 South College Avenue
Rensselaer, Indiana 46978
(219) 866-8008

Indiana Department of Environmental
Management Watershed Coordinator
(765) 564-4480

This pamphlet was produced by:
J.F. New & Associates, Inc.
708 Roosevelt Road
Walkerton, Indiana 46574
(574) 586-3400

If you have any questions regarding the study or pamphlet, please contact J.F. New & Associates.

The Curtis Creek Watershed Diagnostic Study

Newton and Jasper Counties, Indiana

What is the Watershed Diagnostic Study?

The Curtis Creek Watershed Diagnostic Study is a comprehensive examination of Curtis Creek and its surrounding watershed. In 2002, with funding from the Indiana Department of Natural Resources Lake and River Enhancement (LARE) Program, the Newton County Soil and Water Conservation District hired the team of Indiana University and J.F. New & Associates to conduct the study. The purpose of the study was to describe the historical and existing condition of the watershed, identify potential problems, and make prioritized recommendations addressing these issues. It included a review of historical studies, several mapping exercises, an aerial and windshield tour of the watershed, an assessment of chemical, biological, and physical stream health, and interviews with watershed residents and local and state agencies. This fact sheet summarizes the study results and presents some suggestions for improving water quality in the watershed.

How can the Curtis Creek Watershed be Described?

- ★ The watershed encompasses 26,572 acres of Newton and Jasper Counties and is part of the Iroquois River Basin.
- ★ Soils in the watershed originated as glacial till, which is a mixture of dune sand, lake sediment, and outwash sand and gravel. The soils are predominantly sands, sandy loams, and loams. Blow sand predominates in the northern portion of the watershed.
- ★ The watershed is sparsely populated with an average density of 39 people per square mile.
- ★ Land use in the watershed is mostly agricultural:

Agriculture	84.0%
Forest	13.3%
Wetland	1.5%
Urban	1.1%

- ★ The Newton County Health Department, Jasper County Health Department, and the Indiana Department of Environmental Management (IDEM) have each documented water quality concerns in study area streams. In fact, Yeoman Ditch appears on the IDEM 303(d) list of impaired water bodies for nutrients, dissolved oxygen, total dissolved solids, and chlorides. The Iroquois River is also included on the Indiana list of impaired waterbodies for *E. coli* bacteria.

What did the Diagnostic Study Find?

- ★ Only about 163 acres of the 26,572-acre watershed are currently enrolled in the Conservation Reserve Program (CRP).
- ★ Most of the major soil types in the watershed are moderately to severely limited for proper septic system function. Nitrate and pesticide leaching risk was also found to be high to very high in some areas of the watershed.

- ★ Three confined feeding operations operate within the Curtis Creek Watershed These operations house 18,000 dairy cattle and 7,050 hogs which generate approximately 12.5 million cubic feet of manure per year.
- ★ *E. coli* concentrations in the watershed were 2 to 51 times the Indiana state standard. Several other stream chemistry parameters also indicate water quality problems. For example, one ammonia-nitrogen concentration was nearly 45 times the Indiana state standard in the mainstem of Curtis Creek.
- ★ An aerial and windshield tour revealed several locations where conservation practices could be implemented. Examples of such practices include wetland restoration, filter strip installation, stream bank stabilization, livestock fencing, revegetation of exposed areas, and grassed waterway installation.
- ★ Based on stream macroinvertebrates collected during the study, Curtis Creek and its tributaries exhibit varying degrees of impairment. Poor habitat quality due to ditching, dredging, and straightening of stream channels, riparian vegetation removal, and livestock grazing of stream banks limit the biotic health and water quality within the Curtis Creek Watershed.

What can YOU do to Improve Your Water Quality and Reduce Soil Loss?

Some of the larger-scale, long-term projects include:

- ★ Utilizing conservation program cost-share monies to implement best management practices and projects based on subwatershed priority. The top three prioritized areas include the drainages of Yeoman Ditch, Long Ditch, and Curtis Creek north of State Road 114.
- ★ Coordinating conservation projects with county drainage boards to ensure that the projects meet drainage and conservation goals. Curtis Creek has been petitioned for assessment. If conservation practices are applied immediately following drain maintenance, it may reduce the need for future maintenance and improve long-term drainage.
- ★ Extending management to the watershed-level. Examples of working at the watershed level include implementing nutrient, pesticide, and tillage management plans and coordinating complementary projects in priority subwatersheds.
- ★ Developing a comprehensive plan to provide information about water quality and on-going projects in the Curtis Creek Watershed and throughout Newton County. Understanding the value of good water quality and healthy streams is the first step towards conserving these valuable resources.